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Outsourcing and Volatility

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Abstract:

While outsourcing of production from the U.S. to Mexico has been hailed in Mexico as a valuable engine of growth, recently there have been misgivings regarding the fickleness and volatility of this engine. This paper is the first in the literature to focus on the second moment properties of outsourcing. We begin by documenting a new stylized fact: the maquiladora outsourcing industries in Mexico experience fluctuations in value added that are roughly twice as volatile as the corresponding industries in the U.S. A difference-in-difference method adapted to second moments is used to verify that this finding is specific to the outsourcing sector and is statistically significant. We then develop two theoretical models of outsourcing that can explain this stylized fact. Both models rely on a continuum of products and many varieties of each product. In the first model, firms can enter into outsourcing relationships via new products and new product varieties, with CES preferences. In the second model, firms enter into outsourcing only via new product varieties, and the degree of entry is modulated by a novel mechanism of endogenous markups obtained from translog preferences. Stochastic simulations show that both models can replicate many of the second moment properties in the data. In particular, domestic demand shocks in the U.S. are transmitted in an amplified manner to Mexican outsourcing industries.

JEL classification: F1, F4

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I. Introduction

Outsourcing, the arrangement whereby firms contract with independent counterparts in another country to carry out particular stages of production, has grown over the last fifteen years to become an important part of the trade relationship between the U.S. and Mexico. It is also of growing importance for trade between the EU and emerging economies in Europe, and in trade with China. In Mexico, employment in outsourcing industries grew ten-fold from 0.12 mil in 1980 to 1.3 mil in its peak year 2000. While it accounted for under 3% of total Mexican GDP, it counted for more than 20% of Mexican value added and for nearly half of the country's exports. While Mexican officials have hailed outsourcing as a source of growth for their country, some have also complained that it is highly fickle, being a source of excessive volatility.[1] The question has been raised as to whether outsourcing can act as a channel by which the U.S. exports to Mexico some of its employment fluctuations over the business cycle. While there is a large literature studying outsourcing and its implications for the volume of trade, wage levels, and environmental regulation,[2] there is little to no work done on second moment implications of outsourcing. This paper aims to help fill this gap.

We begin by documenting a stylized fact regarding second moments in outsourcing in Mexico. Data is collected from Mexican national sources on employment and value added for firms engaging in outsourcing, commonly referred to as 'maquiladoras.' Our data set covers maquiladoras in four industries which together account for three quarters of outsourcing production in Mexico: apparel, transportation equipment, electronics, and other electrical machinery. Industry level data from the U.S. national accounts are then used to construct four industry classifications for the U.S. that closely correspond to the four maquiladora industries defined in the Mexican data. We find that for all four industries the volatility in Mexico is significantly higher than in the corresponding U.S. industry; averaging over the four industries, we find that volatility is twice as high in Mexico as in the U.S. One conjecture is that this simply reflects higher volatility in Mexico in general. While volatility in overall Mexican manufacturing is higher than in the U.S., the gap is much less than that found for the maquiladora industries. A difference in difference regression adapted for second moments is used to show that there is a statistically significant difference between Mexican and U.S. volatility in the outsourcing industries, even after controlling for cross-country differences in aggregate manufacturing volatility.

We then develop two theoretical models of outsourcing that can explain this stylized fact. Both models rely on a continuum of products in the outsourcing sector, and for each product an endogenous number of varieties. This structure combines the Dornbusch-Fisher-Samuelson (1977) framework with

[1] See for example the news account of how the Mexican car industry is especially susceptible to fluctuations in demand for American brand automobiles in Dickerson (2005).
[2] See Feenstra and Hanson (1996, 1997), and Grossman and Helpman (2002, 2005) for examples.

the monopolistic competition model, as also done by Romalis (2004). Production in the outsourcing sector requires two activities: a fixed cost activity that takes place in the home country, representing headquarter costs, and a variable cost activity representing assembly work that can be outsourced. In the first model, the point along the product continuum at which firms begin to outsource is endogenously determined as firms compare the unit labor costs across countries. This version of outsourcing is similar to the structure used by Feenstra and Hanson (1996, 1997), except that we also allow firms to enter and exit new varieties of each product, with CES preferences.

A second version of the model treats the borderline outsourced product as fixed, but still allows firms to enter and exit new varieties of each product. In this case we employ a novel specification of preferences obtained from a translog expenditure function, which has the very convenient property that the elasticity of demand for each product variety is equal to the number of firms in that industry.[3] As a result, markups charged by firms are countercyclical, and stochastic increases in demand are not automatically fully absorbed by new entrants: rather, increases in demand are split between entry of new firms and increasing firm size. Similar reactions to a change in market size could be obtained from the model of Melitz and Ottaviano (2005), but the translog expenditure function has the convenient property that preferences are still homothetic, so that two-stage budgeting can be used.

The outsourcing sector is embedded in a two country, general equilibrium trade model, which also includes an undifferentiated traded good in each country. The model is calibrated, and stochastic simulations are used to track implications for second moments when the model is subjected to a set of demand and supply shocks. Both models do a remarkably good job in replicating the stylized fact of amplified volatility in the outsourcing sector, but using the endogenous adjustment of the extensive margin of outsourcing is especially important. When the home country experiences a boom, the fact that wages in that country tend to be procyclical alters the outsourcing decision of some firms. If home workers become relatively more expensive to hire, firms who previously had not outsourced now find it profitable to begin outsourcing. This extensive margin shift acts as a powerful mechanism of international transmission, whereby U.S. producers act strongly to shift unusually high levels of production abroad during a domestic boom period, and the reverse during recession periods. Even when the shock is a purely domestic one, the simulation shows that it is amplified in its transmission abroad, so that it has a greater impact on the foreign outsourcing industries than on the domestic counterpart industries.

The next section presents the data and new stylized fact. Section 3 presents the model, and section 4 discusses results from stochastic simulations of this model.

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[3] The translog expenditure function is used by Bergin and Feenstra (2000, 2001), but with a fixed number of product varieties. Feenstra (2003) shows how the reservation prices are solved for when varieties enter and exit, and substituting the reservation prices back into the expenditure function yields the functional form used here.

II. Data and Stylized Facts

Outsourcing by the United States to Mexico generally takes the form of U.S. firms producing parts and components, exporting these intermediate inputs to Mexico to be assembled or processed into final goods, and re-importing the finished products. U.S. firms tend to specialize in R&D, component production, marketing, and other headquarters activities, while Mexican firms, known as *maquiladoras*, tend to specialize in assembly services.[4] Mexico is among the most important locations for global outsourcing by U.S. firms and the United States is by far and away Mexico's largest trading partner. Over the period 2000-2003, the United States was the source country for 73.4% of the inputs imported by maquiladoras in Mexico and maquiladora exports back to the United States were equal to 5.3% of U.S. industry shipments (U.S. International Trade Commission, 2005).[5] Maquiladoras have become an integral part of the Mexican economy, with their share of national manufacturing employment rising from 4.1% in 1980 to 28.3% in 2002 (Hanson, 2006).

Most outsourcing by U.S. firms in Mexico occurs in one of four industries: apparel, electronic accessories (including computer parts and electronic circuitry), electrical machinery (including televisions and small domestic appliances), and transport equipment and parts (primarily motor vehicles). Figure 1 shows that over 1990 to 2005 these four industries accounted for 72.7% of employment in the maquiladora sector. Several common features of these industries make them amenable to global production sharing. Their production stages—R&D, component production, final assembly—tend to be physically separable. Firms need not perform all tasks in the same location, allowing them to allocate stages across countries. Production stages also vary in their factor intensity, with R&D and component production being more skill and capital-intensive and assembly being more labor-intensive, giving multinational firms an incentive to locate labor-intensive activities in low-wage countries.

Mexico first began to allow export assembly plants to operate in the country in the 1960s. The maquiladora sector did not reach an appreciable size until the government relaxed restrictions on inbound

[4] The Mexican government measures imports and exports by registered export-assembly plants in Mexico. Under Mexican trade policy, firms that export their output do not have to pay duties on any imported intermediate inputs used in production. To obtain duty-free status, a firm must register with the government. While under the North American Free Trade Agreement imports from the United States are not subject to duties in Mexico, imports from most other countries are. As a result, the vast majority of export-assembly plants in Mexico are registered. (Strictly speaking, export-assembly plants in Mexico may be registered either as maquiladoras or as PITEX (Program for Temporary Imports of Articles to be Exported) companies (see http://www.economia.gob.mx/). Only the former appear in our data. In 2003, maquiladora exports to the United States were 2.2 times those by PITEX companies.)

[5] These figures apply to the four core outsourcing industries, described in the text. Comparing U.S. imports from Mexico to U.S. industry output may give a deceptive sense of the size of Mexico's maquiladora sector relative to U.S. manufacturing. U.S. imports from Mexico include a substantial component of U.S. value added, in the form of the intermediate inputs produced in the United States and sent to Mexico for further processing. As an alternative measure of relative size, one might examine value added in the two countries. Over the period 2000-2003, the ratio of value added in Mexico's maquiladoras to value added in U.S. manufacturing was 0.034 in the four core outsourcing industries (based on annual data).

foreign investment in the 1980s. Initially, U.S. firms outsourcing to Mexico received favorable tariff treatment under the HS9802 provision of the U.S. tariff code (Feenstra, Hanson, and Swenson, 2000). Under HS9802, U.S. firms that manufacture components at home and have them processed into final goods abroad pay duties on the foreign value-added only when the goods are brought back into the United States. The North American Free Trade Agreement ended special tariff treatment for U.S. firms outsourcing to Mexico. But, as Figure 2 shows, it did not slow growth in production sharing. Growth in real value added by maquiladoras accelerated after NAFTA was implemented, increasing by over 100 log points between 1994 and 2005. Far from removing the incentive for Mexico to specialize in assembly services, NAFTA freed resources Mexico had devoted to domestic production to move into export assembly.

Of primary interest to our analysis is the relative variance of output in U.S. manufacturing industries and the plants to which they outsource in Mexico. Ideally, we would like to measure output using value added. However, data constraints require us to use the industry wage bill, instead. At the three-digit industry level, monthly data on value added, input purchases, and labor earnings (for production and nonproduction workers) are available for maquiladoras in Mexico, but no such data are available for the United States. The only monthly U.S. industry series available are an industry production index, which is not directly comparable to value added, and the wage bill for production workers, which is a substantial component of value added.[6] We compare the monthly variation in the production-worker wage bill in the two countries at the industry level. We match Mexico's four primary outsourcing industries (assembly of apparel items, electronic materials and accessories, assembly of electrical machinery and equipment, and construction and assembly of transport equipment and parts) with their closest U.S. three-digit industry matches (apparel manufacturing, NAICS 315; computer and electronic product manufacturing, NAICS 334; electrical equipment, appliance, and component manufacturing, NAICS 335; and transportation equipment manufacturing, NAICS 336).

To provide a visual sense of the relative variation in industry activity in the two countries, Figure 3 plots the production-worker wage bill for the four core outsourcing industries over the sample period. Each series is in log terms, deflated by the national CPI. To remove seasonal fluctuations and time trends, each series is seasonally adjusted and HP filtered. In each industry, economic activity in Mexico is substantially more volatile than in the United States. Table 1, which shows the ratio of the standard deviations for the wage bill in Mexican and U.S. industries, reinforces this perception. To avoid the contaminating effects of the Mexico peso crisis in 1994-1995, which are evident in Figure 3, we examine standard deviations for the period 1996-2005. In each industry, the standard deviation of Mexican

[6] In U.S. manufacturing, the production-worker wage bill accounts for 27.8% of value added; in Mexico's maquiladora sector, the comparable figure is 19.0%.

earnings is greater than in the United States, with the Mexico-U.S. ratio ranging from 4.7 in apparel to 6.6 in electronics.

Of course, Mexican industries may be more volatile than their U.S. counterparts simply because at an aggregate level the Mexican economy is more volatile than the U.S. economy. To control for such differences in aggregate volatility, Table 1 also shows the relative standard deviation in the industry wage bill in the two countries divided by the relative standard deviation either for the production index of all manufacturing industries (available for the entire time period) or the production-worker wage bill for all manufacturing industries (available from 1993 forward). While overall manufacturing in Mexico is more volatile than in the United States, the relative volatility of Mexico's maquiladora industries is even greater. The Mexico-U.S. standard-deviation ratio, adjusted for aggregate manufacturing standard-deviation ratio, ranges from 1.9 in transport equipment to 2.4 in electronics.

Another concern is that the size of the two economies may affect their estimated relative volatilities. If a Mexican manufacturing industry is small and its U.S. counterpart is large, the variance in the Mexico industry wage bill may larger than for the U.S. simply because summing over a larger number of plants in the United States tends to smooth out shocks idiosyncratic to plants. This issue is of concern only where Mexican industries are small in an absolute sense. While Mexico's maquiladora industries are smaller than U.S. manufacturing industries, they are still large by any reasonable scale. Over the sample period, Mexico apparel employment averages 216,000 workers versus 487,000 in the U.S.; Mexico electronics employment averages 256,000 workers versus 1.64 million in the U.S.; Mexico electrical machinery employment averages 93,000 workers versus 539,000 in the U.S.; and Mexico transport equipment employment averages 215,000 workers versus 1.94 million in the U.S.[7]

To examine the relative volatility of Mexican and U.S. outsourcing industries more formally, we test whether the variability of the industry wage bill differs between the two countries, controlling for aggregate differences in volatility. Let Y_{ict} be the wage bill for production workers in industry *i*, country *c* (*c*=Mexico, United States), and time *t*. An industry may be one of the four outsourcing industries, in which case *i=o*, or the aggregate across all manufacturing industries (and not just outsourcing industries), in which case *i=m*. A standard measure of industry variability is the squared deviation from the mean, $(Y_{ict} - \overline{Y}_{ic})^2$, where $\overline{Y}_{ic}$ is the mean value of the wage bill in industry *i* and country *c* over the sample period.

For each of the four outsourcing industries, we pool observations on $(Y_{ict} - \overline{Y}_{ic})^2$ across countries

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[7] A separate issue is whether for a given scale U.S. industries tend to be more diversified than Mexican industries, which is difficult to evaluate with available data.

and time. Then, we add to this sample pooled observations on $(Y_{ict} - \bar{Y}_{ic})^2$ in aggregate manufacturing in the two countries, yielding a data set with 2*2*T observations, where T is the number of months in the sample period. Using these data, we estimate the following regression for each combination of an outsourcing industry with aggregate manufacturing:

$$(Y_{ict} - \bar{Y}_{ic})^2 = \beta_0 + \beta_1 * 1[i = o] + \beta_2 * 1[c = MX] + \beta_3 * 1[i = o] * 1[c = MX] + \varepsilon_{ict}$$

where $1[i=o]$ equals one if industry i is an outsourcing industry and zero if industry i is a manufacturing aggregate, $1[c=MX]$ equals one if country c is Mexico and zero if country c is the United States, and ε_{ict} is a disturbance term we discuss below.

The regression equation is a difference-in-difference estimator of the variability of industry activity. The coefficient β_3 identifies the difference in the variability of the wage bill specific to outsourcing industries in Mexico, controlling for aggregate differences in variability between Mexico and the United States (captured by the main effect on the Mexico dummy, β_2) and differences in variability between outsourcing industry o and aggregate manufacturing (captured by the main effect on the outsourcing industry dummy, β_1). Given the regressand is the square of a variable, the error term is likely to have a non-spherical distribution, complicating inference on the regression parameters. We use bootstrap methods to obtain standard errors for the coefficient estimates. By estimating the regression for each outsourcing industry separately, we allow Mexico-U.S. relative volatility to vary across industries. We estimate the regression over two periods, the sample for which aggregate manufacturing data are available (1992-2005) and the period following the implementation of NAFTA (1996-2005).

Table 2 shows that for either sample period the variability of the wage bill in Mexico's outsourcing industries is higher than in corresponding U.S. industries, controlling for the difference in binational variability for aggregate manufacturing. For three of the four industries (all except apparel), the difference in relative variability is very precisely estimated. Not surprisingly, variability in the wage bill is higher for outsourcing industries than for aggregate manufacturing (as shown by the positive and significant main effect on the outsourcing industry dummy) and higher for Mexico than for the United States (as shown by the positive main effect on the Mexico dummy). We obtain similar results when we replace the aggregate manufacturing wage bill with the aggregate manufacturing production index, in which case the control is the relative variability of manufacturing production in the two countries. These results suggest that economic activity in industries engaging in high levels of outsourcing is higher in the country specializing in labor-intensive product assembly (Mexico) than in the country specializing in skill-intensive headquarters operations and component production (the U.S.).

The sample period spans the implementation of NAFTA, which lowered barriers to trade and foreign investment between Mexico and the United States. Lower trade and investment barriers have allowed U.S. firms to expand their outsourcing of production activities to Mexico. Table 2 also shows that the relative variability of economic activity in Mexico's outsourcing industries is highest in the post-NAFTA period, shown by the positive coefficient on the outsourcing, Mexico, post NAFTA interaction in the final triple-difference regression.

III. Theoretical Model

A. Pricing and Product Variety

Consider a model of two countries, labeled home and foreign. The outsourcing relationship in this model is characterized by the home country outsourcing to the foreign country, so that home may be thought of as representing the U.S. and foreign represents Mexico. We will scale the quantity variables coming from the foreign country by its relative size: if the share *n* of the world population resides in the home country and *1-n* in the foreign country, then we scale foreign quantities by *(1-n)/n*. Foreign variables will be denoted by an asterisk *.

Each country has two sectors. The first is a standard nondifferentiated good whose production is specific to that country; this will be subscripted by *H* for the home country's domestically produced good, and *F* for the foreign good. The second sector consists of differentiated products that are multinational, subscripted by *M,* in that they can be produced using factors in either country. This sector represents the aggregate of the four industries listed in the empirical section above, and it sometimes will be referred to as the outsourcing sector. There is a continuum of products in this sector indexed by $z \in [0,1]$, and for each *z,* there is free entry of firms who then produce *N(z)* differentiated varieties of input *z*. So the model follows Romalis (2004) in combining a continuum of products *z* in the *M* sector along with multiple varieties *N(z)* of each product.

The main contribution of the model is to propose a theoretical description of outsourcing that can broadly replicate the stylized facts above. Production in the outsourcing sector involves a fixed cost activity as well as a variable cost activity. The fixed cost, *B*, represents headquarters and R&D services. It is assumed here to be uniform across goods and takes place in the *home* country, due to the assumption that it is sufficiently more productive in these activities. The variable cost activity has a unit labor cost that differs by variety, and follows the decreasing distribution $a_M\left(z\right)=\exp\left(az+b\right)$. The share of outsourcing varieties $z_t^{'}$, is determined by the relative wages across countries (W_t and W_t^*)

$$A(z_t^{'})=\frac{a_M(z_t^{'})}{a_M^*(z_t^{'})}=\frac{W_t^*}{W_t} \tag{1}$$

Overall demand for this sector in the home country is specified as

$$\ln D_{Mt} = \int_0^1 \ln d_{Mt}(z)dz \qquad (2)$$

where $d_M(z)$ is the aggregated demand for a variety *z*. This in turn is equated to

$$d_{Mt}(z) = \begin{cases} N_t(z)p_t(z)y_t(z) & z \geq z_t^{'} \\ N_t(z)p_t(z)y_y^*(z) & z \leq z_t^{'} \end{cases}$$

where $N_t(z)$ is the number of firms in the industry, $p_t(z)$ is the price (equal across product varieties), and $y_t(z)$ the level of production in each firm. Under our assumptions that the fixed cost and weight in demand are both are uniform across varieties, then the number of entrants likewise is uniform across varieties, so N_t does not vary with *z*. We choose the multinational good D_{Mt} as the numeraire.

The number of entrants depends on the market structure assumed for each variety. If we assume a CES specification of preferences over entrants within a variety with elasticity σ, the number of entrants will be

$$N_{CES,t} = \frac{D_{Mt} + D_{Mt}^* \left(\frac{1-n}{n}\right)}{\sigma B W_t} . \qquad (3)$$

That is, the number of entrants in the CES specification is directly proportional to demand. This is a well-known result in the CES case, but works against finding any difference in the employment volatility in our model between the home and foreign countries. Even though all the fixed-cost activities take place at home, those activities are not any less volatile than the variable cost activities when entry is proportional to demand, as in (3). So in order to find some difference in the output and employment volatilities across countries in the CES case, we will rely on changes in the outsourcing margin $z_t^{'}$, determined by (1). This version of outsourcing is similar to the structure used by Feenstra and Hanson (1996, 1997), except that here we also allow firms to enter and exit new varieties of each product.

Alternatively, we will also consider preferences over varieties that are not CES, but instead follow a translog form, where the unit-expenditure function over the varieties of each product *z* is

$$e(p_t, z) = \sum_{j=1}^{N_t(z)} \frac{\ln p_{it}(z)}{N_t(z)} + \tfrac{1}{2} \sum_{i=1}^{N_t(z)} \sum_{j=1}^{N_t(z)} \gamma_{ij} \ln p_{jt}(z) , \qquad (4)$$

where $p_{it}(z)$ is the price of variety i of product z, and where

$$\gamma_{ij} = \begin{cases} -\gamma \dfrac{N(z)-1}{N(z)}, & i = j \\ \dfrac{\gamma}{N(z)}, & i \neq j \end{cases} \qquad \gamma > 0\,. \tag{5}$$

Notice that the parameters in this translog function vary with the number of products. Feenstra (2003) shows that this specification arises by starting with a symmetric translog function with fixed parameters, and then solving for the reservation price for varieties not available. Substituting these reservation prices back into the translog function, we obtain the specification above. In this specification the elasticity of demand is time varying, but with the added parameter restriction that $\gamma = 1$, then the demand elasticity very conveniently equals the number of entrants. As shown in the Appendix, the number of entrants then follows a "square root formula":

$$N_{TLog,t} = \sqrt{\frac{D_{Mt} + D^{*}_{Mt}\left(\frac{1-n}{n}\right)}{BW_t}} \tag{6}$$

So the translog case naturally gives rise to a dampened response of new varieties to demand shocks, which will generate less volatility in the fixed-cost activities (done at home) as compared to the variable cost activities (done in both countries). When examining the translog case we shall keep the outsourcing margin $z_t^{'}$ fixed for convenience. Our interest, then, will be in comparing the volatility in employment generated by dampened entry (6) in the translog case, to the volatility in employment generated by endogenous outsourcing margin (1) in the CES case.

The overall labor demand in the multinational sector in each country, L_{Mt} and L^{*}_{Mt}, also depends on the particular market structure within varieties. Labor demand at home includes labor used for the fixed cost activity as well as the variable cost activity for varieties not outsourced ($z_t > z_t^{'}$); labor demand abroad includes just variable cost activity for outsourced varieties ($z_t < z_t^{'}$). For CES preferences:

$$\begin{aligned} L_{CES,Mt} &= \left(\frac{D_{Mt} + D^{*}_{Mt}\left(\frac{1-n}{n}\right)}{\sigma W_t}\right)\left(1+(\sigma-1)\left(1-z_t^{'}\right)\right) \\ L^{*}_{CES,Mt} &= \left(\frac{D_{Mt} + D^{*}_{Mt}\left(\frac{1-n}{n}\right)}{W_t^{*}}\right)\left(\frac{\sigma-1}{\sigma}\right)z_t^{'} \end{aligned} \tag{7a,b}$$

For translog preferences:

$$L_{TLog,Mt} = \sqrt{B\frac{D_{Mt} + D^*_{Mt}\left(\frac{1-n}{n}\right)}{W_t}\left(z_t^{'}\right) + \left(\frac{D_{Mt} + D^*_{Mt}\left(\frac{1-n}{n}\right)}{W_t}\right)\left(1-z_t^{'}\right)}$$

$$L^*_{TLog,Mt} = \left(\frac{D_{Mt} + D^*_{Mt}\left(\frac{1-n}{n}\right)}{W_t^*}\right)z_t^{'}\left(1-\sqrt{\frac{BW_t}{D_{Mt} + D^*_{Mt}\left(\frac{1-n}{n}\right)}}\right) \tag{8a,b}$$

The remainder of the model follows a standard open macroeconomy specification. The country-specific sector in the home country is a perfectly competitive market for an undifferentiated traded good with production function

$$Y_{Ht} = \frac{L_{Ht}}{a_{Ht}}, \tag{9}$$

where L_{Ht} is labor in the home country-specific sector and a_{Ht} is labor cost. Profit maximization by producers in this sector implies

$$W_t = \frac{p_{Ht}}{a_{Ht}} \tag{10}$$

where p_{Ht} is the relative price of the home domestic good in terms of the multinational good numeraire.

The representative household in each country has additively separable preferences over consumption (C_t), which is a composite of goods in the three sectors, and overall labor (L_t). We assume complete asset markets in state-contingent securities between countries. The household optimization problem in the source country may be expressed:

$$\begin{aligned}
&\max \quad U = \frac{1}{1-\phi}C_t^{1-\phi} - \frac{1}{1+\mu}L_t^{1+\mu} \\
&st. \quad P_{Ht}C_{Ht} + P_{Ft}C_{Ft} + C_{Mt} + \sum_{s^{t+1}} v\left(s^{t+1} \mid s^t\right)X\left(s_{t+1}\right) = W_tL_t + X_t \\
&where \quad C_t = \left(C_{Ht}^{\ \theta}C_{Ft}^{\ 1-\theta}\right)^{1-\alpha}C_{Mt}^{\ \alpha}
\end{aligned}$$

and where X_t is the holdings of Arrow-Debreu securities that pay off in units of the numeraire multinational good in state *s*. Likewise for the foreign country.

Labor is mobile between sectors within a country, and between fixed and variable cost activities within the home outsourcing sector, but there is no labor mobility between countries. So each country has a single but distinct equilibrium wage rate.

Complete asset markets implies the following risk-sharing condition equating the marginal utilities of consumption up to a constant of proportionality

$$\frac{L_t^{\mu}}{W_t} = \omega \frac{L_t^{*\mu}}{W_t^{*}}, \tag{11}$$

where ω is a constant indicating the relative per-capita wealth of the home country in the initial asset allocation. Relative demand for the home and foreign local goods follow:

$$\frac{C_{Mt}}{C_{Ht}} = \left(\frac{\alpha}{\theta(1-\alpha)}\right) P_{Ht} \tag{12}$$

$$\frac{C_{Mt}}{C_{Ft}} = \left(\frac{\alpha}{(1-\theta)(1-\alpha)}\right) P_{Ft}. \tag{13}$$

Note that the law of one price holds here, so the relative prices P_{Ht} and P_{Ft} apply to the goods markets in both countries. And labor supply is

$$L_t = \left(\frac{W_t}{C_{Mt}}\right)^{\frac{1}{\mu}}. \tag{14}$$

Corresponding conditions apply for the foreign country.

An exogenous component of demand will be denoted G_t, which could be interpreted as government expenditure or perhaps demand from an exogenous third country. This government demand is allocated among the three goods in the same way as private consumption, according to demand conditions like (12 and 13) above. We denote total demands as the sum of consumption and government demand: $D_t = C_t + G_t$, $D_{Mt} = C_{Mt} + G_{Mt}$, etc.

The market clearing condition for domestic good in the home country is

$$C_{Ht} + \left(\frac{1-n}{n}\right) C_{Ht}^{*} + G_{Ht} + \left(\frac{1-n}{n}\right) G_{Ht}^{*} = Y_{Ht} \equiv \frac{L_{Ht}}{a_{Ht}}. \tag{15}$$

Market clearing in the labor market requires that overall labor supply equal the sum of labor demands in the sectors

$$L_t = L_{Ht} + L_{Mt} \tag{16}$$

$$L^{*}_t = L^{*}_{Ft} + L^{*}_{Mt}$$

Equilibrium here is a sequence of 19 endogenous variables: L_t, L_t^{*}, L_{Ht}, L_{Ft}^{*}, L_{Mt}, L_{Mt}^{*}, W_t, W_t^{*}, N_t, N_t^{*}, C_{Ht}, C_{Ht}^{*}, C_{Ft}, C_{Ft}^{*} C_{Mt}, C_{Mt}^{*}, p_{Ht}, p_{Ft}, and $z_t^{'}$, which are determined by the Labor supply condition (14), relative demand for the home country-specific good (12), that for the foreign country-specific good (13), optimal entry condition (3 or 4), labor demand for the country-specific sector (10), and the multinational sector (7 or 8), market clearing condition for the country-specific sector (15), labor (16), and foreign counterparts for each of these. In addition there is the marginal outsourcing condition (1), the risk sharing condition in (11). The price of the numeraire good D_{Mt} is set to unity (as described in the Appendix).

Finally, value added in each sector (in units of the multinational goods numeraire) can then be computed as

$$
\begin{aligned}
&Y_t = W_t L_t, \quad Y_{Mt} = W_t L_{Mt}, \quad p_{Ht} Y_{Ht} = W_t L_{Ht} \\
&Y_t^* = W_t^* L_t^*, \quad Y_{Mt}{}^* = W_t^* L_{Mt}{}^*, \quad p_{Ft}{}^* Y_{Ft}{}^* = W_t{}^* L_{Ft}{}^*
\end{aligned}
\tag{17}
$$

B. Shocks

The model will consider four stochastic shocks. Two of these will be to the additive demand component in each country. The other two are productivity shocks in each country, which affect the outsourcing and non-outsourcing sectors in parallel.

$$
\begin{aligned}
&\log G \sim N\left(\log \overline{G}, \sigma_G\right) \\
&\log G^* \sim N\left(\log \overline{G^*}, \sigma_{G^*}\right) \\
&\log a_H \sim N\left(\log \overline{a_H}, \sigma_{a_H}\right),\ b \sim N\left(\overline{b}, \sigma_b\right) \\
&\log a_F^* \sim N\left(\log \overline{a_F^*}, \sigma_{a_F^*}\right),\ b^* \sim N\left(\overline{b^*}, \sigma_{b*}\right)
\end{aligned}
\tag{18}
$$

We choose not to introduce shocks specific to the outsourcing sector, but restrict ourselves to standard productivity shocks affecting all manufacturing in parallel. This is to avoid the temptation of tailoring shocks to the outsourcing sector as an easy, and not very informative, way of explaining its special behavior.

For simplicity, these shocks are specified to be serially uncorrelated and uncorrelated across countries. The objective is to study international transmission of shocks, not the propagation of shocks across periods, which is a distinct and difficult question that continues to be explored in other literature. Regarding cross-country correlations, results to follow will show that the endogenous mechanisms for transmission of shocks are sufficiently strong to more than explain the cross-country correlations in output without requiring an exogenous correlation in the underlying shocks.

C. Model Calibration

The parameters characterizing production in the outsourcing sector can be calibrated in part by using data on relative wages across countries. If one computes the average weekly rate of payment to workers for the four outsourcing industries in the data set, workers in the U.S. sector are paid 8 times as much as the Mexican workers. Further, comparing the level of employment in the four outsourcing industries in Mexico and in the U.S., Mexican employment represents 20% of the total over both countries. This is used to calibrate the steady state outsourcing share: $\bar{z}$ =0.20, and thereby, one point on the relative unit cost distribution in condition (1) of the model, $A(0.2)$ =0.125.

These values permit the six productivity parameters ($a, \bar{b}, \overline{a_H}, a^*, \overline{b^*}, \overline{a_F^*}$) to be calibrated as follows. First, we wish to make consistent with each other the overall unit labor cost in the home outsourcing sector and the home domestic good sector, and the means of both will be normalized to unity ($\overline{a_H} = \overline{a_M} = 1$). Second, once the home outsourcing parameter a is also normalized to unity, this pins down the remaining home distribution parameter at $\bar{b} = -\bar{z} = -0.2$, given the definition above that $a_M(z) = \exp(az + b)$. Third, equilibrium condition (1) indicates that $A(0) = \exp\left(\bar{b} - \overline{b}^*\right)$, which may be regarded as a free parameter. This is chosen to maximize the fit of the model to the stylized facts as part of a grid search procedure. This indicates a value of $A(0) = 0.20$, which then pins down the value of $\overline{b^*}$. Next, equilibrium condition (1) also indicates that $A(\bar{z}) = \exp\left(\left(a - a^*\right)\bar{z} + \left(\bar{b} - \overline{b^*}\right)\right)$. Since the data above indicated this equals a value of 0.125, and all the other parameters have already been pinned down, this determines the value of a^* . Finally, the steady state value of unit labor costs in the foreign good sector, $\overline{a_F^*}$, is solved numerically to imply the equilibrium wage in the foreign country indeed is one-eighth that in the foreign country, as indicated by the data above, conditional on the other calibrated parameter values.

The standard deviations of the four productivity shocks ($\sigma_{a_H}, \sigma_{a_F^*}, \sigma_b, \sigma_{b^*}$) are chosen by grid search to maximize the fit of the stochastic simulations to the stylized facts. The optimal values differ by case, and are reported for each set of simulations below.

The size of the fixed cost of entry in the outsourcing sector (*B*) is calibrated so that in steady state each industry in the outsourcing sector has six firms that choose to enter ($\overline{N}$ =6); this requires *B*=0.0087. This facilitates comparison between the translog and CES versions of the model, since the number of entrants will be the elasticity of substitution between goods, which was calibrated for the CES case above at 6.

Regarding preference parameters, calibrations for the most standard of these are taken from the business cycle literature. The elasticity of substitution between goods is set to imply a price markup of 20% (so σ =6). The labor supply elasticity is set at unity, μ =1. The curvature parameter is set at ϕ =2.

The remaining preference parameters are calibrated to reflect the relationship between the U.S. and Mexico in the last year of our data set, 2003. The home bias parameters as set to reflect the share of import expenditures in GDP, θ=0.88, θ^*=0.71. The four U.S. industries classified as outsourcing industries in the data set represent 24% of total U.S. manufacturing, so the outsourcing share parameter is calibrated as $\alpha = 0.24$. The relative weight on the home country in the complete asset market allocation (ϖ) is calibrated so that the model generates in steady state a ratio of home consumption to foreign consumption that is close to ratio of real consumption levels per capita in the data, which is 6.27 (requiring 1/ϖ=37). The steady state level of the additive demand term ($\overline{G}$ and $\overline{G^*}$) is calibrated to represent government spending, and is set to equal 20% of GDP in each country. The U.S. population represents 74 percent of the total population of the two countries combined, so n = 0.74.

IV. Model Results:

A. A useful analytical result

This section demonstrates that the model of outsourcing in section 3 can generate the primary stylized fact in section 2, amplified volatility in the outsourcing sector of the destination country. It then analyzes the model features and shocks most important for this result, and it goes on to study outsourcing as a channel of international transmission of shocks.

Some useful intuition into the relative volatility across countries in this sector can be gained by taking the ratio of the labor demand conditions (7a,b) in the CES case, each multiplied by its country's wage to find value added:

$$\frac{Y^*_{Tt}}{Y_{Tt}} = \frac{W^*_t L^*_{CES,Tt}}{W_t L_{CES,Tt}} = \frac{\left(D_{Mt} + \left(\frac{1-n}{n}\right)D^*_{Mt}\right)\left(\frac{\sigma-1}{\sigma}\right)z'_t}{\left(\frac{D_{Mt} + \left(\frac{1-n}{n}\right)D^*_{Mt}}{\sigma_t}\right)\left(1+(\sigma-1)(1-z'_t)\right)} = \frac{(\sigma-1)z'_t}{1+(\sigma-1)(1-z'_t)}. \quad (18)$$

Note that if the outsourcing margin were to taken to be taken to be a constant, then this ratio is would also be a constant, and value added across countries are directly proportional to each other.

This may seem surprising, since the U.S. engages a portion of its labor in this sector in a fixed cost activity, which by definition does not vary when a firm raises its level of production. However, the free entry condition (3) indicates that the number of firms producing each variety rises in direct proportion with demand in the CES case, so that the expenditure on the fixed cost rises likewise in proportion. In essence, the market accommodates the rise in demand by replicating firms without any increase in average firm size. Labor demand for the fixed cost activity rises in proportion to labor demand for the variable cost activity in this case, so the fixed/variable distinction has no bearing on the volatility of value added across the two countries. There are two readily apparent ways to break this linkage. First, we can allow the outsourcing margin to be endogenous, so that the term *z'* in equation (18) above varies, thus implying the ratio of income on the left side of that equation also to vary over time. A second approach will be to introduce sluggishness in the entry of new firms, thus preventing the fixed cost activity in the source country from mimicking volatility in the variable cost activity abroad. Using translog preferences in the model turns out to have this implication. We consider each of these approaches in turn.

B. Endogenous Outsourcing

The first case we study follows the approach of allowing the outsourcing margin (*z'*) to respond endogenously to shocks. Analytical results are not possible for this case, so results from stochastic simulations are reported in Table 3.[8] The first column reports statistics for an optimized weighting of the four shocks.[9] Note that the model replicates the major stylized facts fairly well. It very closely matches the volatility of the outsourcing sector in Mexico, and the ratio of this to the U.S. counterpart represents over a 100% increase, as in the data. Recall that this result was shown analytically not to be possible in the simpler version of the model in equation (18). Further, the ratio of national manufacturing volatilities is near the empirical value in the empirical data in Table 1, and the ratio of ratios (outsourcing over general manufacturing) is well able to explain the range of values in Table 1. Finally, all of the correlations across countries and sectors are positive, as in the data.[10]

The remaining columns of Table 3 simulate the case of each of the fours shocks in isolation, retaining their weights from the optimized mix in column 1. Note that the home demand shock accounts for about half of the volatility in the foreign outsourcing sector, and this shock alone has the best fit to the stylized facts. The main shortcoming is that it does not imply enough volatility in the rest of the foreign manufacturing economy, as this would be less than in the home country under this shock alone. But this

[8] 10,000 draws were made from the distribution of the shocks, and fed into the nonlinear model to find equilibrium values of the endogenous variables. Since the data in the empirical section 2 were all deflated by the national CPI, we do the same to the simulated data here.

[9] A grid search was conducted, maximizing the fit of the simulated standard deviations to the empirical counterparts in Table 1. The particular criterion of fit was the sum of squared deviations for the standard deviation of the outsourcing sector in Mexico (row x), the ratio of total manufacturing standard devations Mexico ove the U.S. (row y), and the overall ratio (row z). The optimal weights are: 3.4 for the home demand shock, 8.2 for the foreign demand shock, 1.9 for the home productivity shock, and 0.2 for the foreign productivity shock.

[10] One possible shortcoming in the result is that, although the simulation explains very well the cross-country gap in volatility between Mexican and U.S. outsourcing sectors, it fails to completely explain the within-country gap in volatility between Mexican outsourcing and overall Mexican manufacturing. While the simulation is able to explain outsourcing volatility in the destination country that is twice as high as overall manufacturing, the data in Table 1 show the volatility is actually over three times as high.

shortcoming in overall foreign volatility is easily fixed by the addition of foreign shocks, mainly to foreign productivity.

There is a clear and intuitive reason for why the endogenizing of the outsourcing margin is so useful here in replicating the distinctive volatility in the outsourcing sector. When the home country experiences a boom, the data tell us the home wage is procyclical and tends to rise relative to the foreign.[11] This affects the outsourcing decision and raises the outsourcing margin. If home workers are more expensive, firms who previously had not outsourced now find it profitable to begin outsourcing. This extensive margin shift acts as a powerful mechanism of international transmission, whereby U.S. producers act strongly to shift unusually high levels of production abroad during a domestic boom period. Even when the shock is a purely domestic one, the simulation shows that it is amplified in its transmission abroad, so that it has a greater impact on the foreign segment of the outsourcing industry than on the domestic segment. The reverse applies equally well during a recession: as U.S. relative wages dip during a recession, firms near the margin cease outsourcing, so that a larger share of the impact of unusually low production hits the Mexican economy. Such a story seems highly plausible and relevant for the U.S.-Mexico relationship, and it corresponds quite well with the empirical ratios and correlations for U.S. and Mexican data in Table 1.

Lastly, we take stock of outsourcing as a means of international transmission of shocks. Is outsourcing any different from normal trade as a mechanism for international transmission? Note that under the endogenous outsourcing case from Table 3, that the correlation between overall manufacturing in the two countries is very high 0.70. This may be compared to a version of the model where the outsourcing sector is removed, by setting the outsourcing share parameter (α) near zero. Using the same weighting of shocks as in the endogenous outsourcing case, the cross-country correlation of overall manufacturing falls, to a somewhat lower value of 0.65. This is still a very high correlation, due in large part to the assumption of complete asset markets between countries.[12] And the effect is fairly small in magnitude, due in large part that outsourcing is a fairly small compared to overall manufacturing. Nonetheless, the result shows that outsourcing of multinational goods tends to transmit shocks internationally to a greater degree than does normal trade in domestically produced goods. The effects of

[11] A boom driven by a home demand shock clearly can have this effect on relative wages. When a shock raises overall demand in the home country, home bias dictates that it require a greater rise in labor demand in the home country, which in turn drives up the real wage of the home country compared to the foreign country. Although government demand shocks in some model may have surprising effects on labor supply due to their negative effects on intertemporal wealth, these are diluted here here. Because of complete asset markets, such wealth effects are pooled between the countries, allowing real wages to rise in response to the rise in labor demand, as described above.

[12] This correlation is significantly higher than that found for the data in Table 1. The assumption of complete asset markets also means that the model here is not well suited for trying to explain some of the cross-country puzzles in the real business cycle literature, such as the consumption correlation puzzle, real exchange rate puzzle or the Backus-Smith puzzle.

outsourcing on aggregate correlations are likely to grow further as outsourcing grows in size and scope over time.

C. Translog Preferences and Limited Entry

We next study the approach of limiting entry of new firms in response to shocks. This implies that the fixed cost activity, which is located exclusively in the home country, will indeed be less volatile than the variable cost activity, which is sole use of labor in the foreign country. Translolg preferences turn out to be a highly convenient way of limiting firm entry. Comparing the entry conditions for the CES and translog cases in the model above (equation 3 and 4), the percentage elasticity of entry in response to a rise in expenditure is one half as large under translog preferences compared to CES, due to the square root radical in equation 4. Entry response is reduced because the price elasticity of demand equals the number of entrants under translog preferences (see appendix). Suppose there is a rise in demand for goods in the outsourced sector which would lead to a rise in profits and entry of new firms. As firms enter, the degree of competition among firms rises, raising the demand elasticity and lowering the markup. This reduces the profits of new entrants, and entry will cease at a lower number of firms than under CES preferences.

Table 4 reports simulation results for the translog case, showing that reduced entry is helpful in replicating the volatility of the outsourcing sector. For the optimized weighting of shocks, the model does a very good job of replicating the volatility of the Mexican outsourcing sector (row 1), and the ratios of Mexican to U.S. volatility in the outsourcing sector and overall economy (rows 5-7). While these results are encouraging, one prominent shortcoming is that the simulation implies the volatility in overall Mexican Manufacturing is just as high if not higher than the outsourcing sector, which conflicts with the empirical facts in Table 1. The explanation for this shortcoming comes from the implication of translog preferences that markups and profits per sale fall in the outsourcing sector as firms enter in response to a rise in sales. As a result, it is more profitable during a boom to shift production away from the outsourcing sector toward the domestic sectors of the home and foreign countries. This is reflected in the correlation reported in Table 4, where a rise in home or foreign demand leads to a fall in employment in the outsourcing sector in both countries at the same time it rises in the domestic sectors.[13]

---

[13] An alternative means to restrict entry of new firms would be to specify that entry is predetermined one period. Given that the shocks in this model are serially uncorrelated and there are no intertemporal dynamics, this is equivalent to simply specifying that the number of firms is exogenously fixed. While this assumption is rather mechanical and admittedly extreme, it is still fairly effective in helping replicate the high volatility of outsourcing. It generates a ratio of volatilities that is somewhat below that in the data, and below that generated in the translog case. But the standard deviation of the outsourcing sector is less than the overall volatility in the destination country, so it is less subject to the shortcoming noted above that is characteristic of the translog case.

Overall, we conclude that while the translog mechanism to restrict new entry does a respectable job of replicating many of the stylized facts of outsourcing volatility, it matches less of these facts than does the model utilizing an endogenous outsourcing margin. However, the rightmost column of Table 4 show that the translog mechanism for restricting entry may be useful *in combinatio*n with endogenous outsourcing as a means of amplifying the outsourcing volatility ratio above what it otherwise would be with endogenous outsourcing mechanism alone.

V. Conclusion

This paper has studied the second moment properties of outsourcing. It has documented a new stylized fact: the outsourcing industries in Mexico experience fluctuations in value added that are twice as volatile as the corresponding industries in the U.S. A difference-in-difference method adapted to second moments is used to verify the finding is statistically significant and is specific to the outsourcing sector. The paper then developed a new theoretical model of outsourcing which can explain this stylized fact. The model features heterogeneous firms that are free to enter and exit outsourcing relationships, and where the degree of entry of new firms into production is modulated by a novel modeling of countercyclical markups. Stochastic simulations show that modeling the extensive margin response of outsourcing to shocks is key for explaining the stylized fact; this feature implies that domestic demand shocks in the U.S. are transmitted in an amplified manner to Mexican outsourcing industries.

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Appendix

In addition the nondifferentiated goods from each country, consumers purchase the continuum of products in the multinational sectors indexed by *z*. For each *z*, there are $N_t(z)$ products and the unit-expenditure function from consumers is given by (4)-(5). Differentiating this unit-expenditure function with respect to $\ln p_{it}(z)$, we obtain the share $s_{it}(z)$ of variety i in the expenditure on product z:

$$s_{it}(z) = \sum_{j=1}^{N_t(z)} \gamma_{ij} \ln p_{jt}(z), \tag{A1}$$

where the parameters γ_{ij} satisfy (5). The elasticity of demand for each variety is computed as:

$$\eta_{it}(z) = 1 - \frac{\partial \ln s_{it}(z)}{\partial \ln p_{it}(z)} = 1 - \frac{\gamma_{ii}}{s_{it}(z)}. \tag{A2}$$

When prices are equal across varieties in a symmetric equilibrium, $\ln p_{it}(z) = \ln p_t(z)$, then the shares of varieties are also equal, $s_{it}(z) = 1/N_t(z)$. So making use of (5) we rewrite (A2) as:

$$\eta_{it}(z) = 1 + \gamma[N_t(z) - 1]. \tag{A3}$$

With the added parameter restriction that $\gamma = 1$, then we see that $\eta_{it}(z) = N_t(z)$, so the elasticity of demand equals the number of firms in the symmetric equilibrium.

To determine the number of firms we make use of zero profits for each product *z*. Fixed costs for each product variety are BW_t. Since the price of the multinational good is taken as numeraire, then the revenue earned from home plus foreign sales of each variety is $p_{it}(z)d_{it}(z) = s_{it}(z)[D_{Mt} + D^*_{Mt}(1-n)/n]$. In the symmetric equilibrium this equals $[D_{Mt} + D^*_{Mt}(1-n)/n]/N_t(z)$. To obtain profits, equal to revenue minus variable costs, we divide by the elasticity of demand. So in the CES case we divide revenue by σ, thereby obtaining profits $[D_{Mt} + D^*_{Mt}(1-n)/n]/[\sigma N_t(z)]$. Setting this equal to fixed costs BW_t, we solve for the number of products in (3), which is equal for all *z*. Alternatively, in the translog case the elasticity is $\eta_{it}(z) = N_t(z)$, and dividing revenue by this we obtain $[D_{Mt} + D^*_{Mt}(1-n)/n]/N_t(z)^2$. Setting this equal to fixed costs BW_t, we solve for the number of products in (6), which is again equal for all *z*.

Labor demand at home is obtained by integrating over the fixed costs *B* for every product $z \in [0,1]$, and the variable labor costs $ay_t(z)$ for those products $z \in [z_t^{'},1]$:

$$L_t = \int_0^1 BN_t dz + \int_{z_t^{'}}^1 ay_t(z)N_t dz. \tag{A4}$$

The number of varieties N_t appearing in the first integral of (A4) is obtained from (3) or (6). For the second integral, we multiply the labor costs $ay_t(z)$ by the wage W_t, and further multiply by the markup $\sigma/(\sigma-1)$ in the CES case, to obtain the expenditure $[D_{Mt}+D^*_{Mt}(1-n)/n]/N_t$ on each variety. So the expression inside the second integral of (A4) equals $[D_{Mt}+D^*_{Mt}(1-n)/n](\sigma-1)/\sigma W_t$, which is integrated over $z\in[z_t^{'},1]$ and summed with the first integral to yield (7a). In the translog case the logic is similar, except that the markup of price over marginal costs is $\eta_t/(\eta_t-1)=N_t/(N_t-1)$, and N_t is obtained from (6). Evaluating the integrals in (A4) we obtain (8a).

For foreign labor demand we integrate the variable labor costs $a^* y_t^*(z)$ for $z\in[0,z_t^{'}]$:

$$L_t^* = \int_0^{z_t^{'}} a y_t^*(z) N_t dz \,. \tag{A5}$$

Multiplying the labor costs $a^* y_t^*(z)$ by the wage W_t^*, and further multiplying by the markup $\sigma/(\sigma-1)$ in the CES case, we again obtain the expenditure $[D_{Mt}+D^*_{Mt}(1-n)/n]/N_t$ on each variety. So the expression inside the integral of (A5) equals $[D_{Mt}+D^*_{Mt}(1-n)/n](\sigma-1)/\sigma W_t^*$, which is integrated over $z\in[0,z_t^{'}]$ to yield (7b). Again, in the translog case the markup of price over marginal costs is instead $\eta_t/(\eta_t-1)=N_t/(N_t-1)$, and evaluating the integral in (A5) we obtain (8b).

Finally, we need to derive the price index for the numeraire good D_{Mt}, and set this equal to unity. It can be shown that in the CES case the price index is:

$$\ln P_{M,CES,t} = z'_t \ln W_t^* + (1-z'_t)\ln W_t + \ln\left(\frac{\sigma}{\sigma-1}\right) + \left(\frac{a^*-a}{2}\right)(z'_t)^2 + \left(b^*-b\right)z'_t + \frac{a}{2} + b\,, \tag{A6}$$

and alternatively in the translog case:

$$\ln P_{M,T\log,t} = z'_t \ln W_t^* + (1-z'_t)\ln W_t + \ln\left(\frac{N_t}{N_t-1}\right) + \left(\frac{a^*-a}{2}\right)(z'_t)^2 + \left(b^*-b\right)z'_t + \frac{a}{2} + b\,. \tag{A7}$$

Both of these expressions are set equal to unity in the simulations to close the model.

Table 1: Relative Volatility in Mexico and U.S. Outsourcing Industries

	Apparel	Transport Equipment	Electrical Machinery	Electronics	Industry Average
<u>Standard Deviations</u>					
$\sigma(Y_i^*)$ (Mex. Outsourcing Industry)	4.66	4.69	4.68	6.56	5.15
$\sigma(Y_i)$ (U.S. Outsourcing Industry)	2.40	2.70	2.13	2.70	2.48
$\sigma(Y^*)$ (Mex. Aggregate Manufacturing)	1.59	1.59	1.59	1.59	1.59
$\sigma(Y)$ (U.S. Aggregate Manufacturing)	1.36	1.36	1.36	1.36	1.36
$\sigma(Y_i^*)/\sigma(Y_i)$	1.94	1.74	2.20	2.43	2.08
$\sigma(Y^*)/\sigma(Y)$	1.17	1.17	1.17	1.17	1.17
$\dfrac{\sigma(Y_i^*)/\sigma(Y_i)}{\sigma(Y^*)/\sigma(Y)}$	1.66	1.49	1.88	2.08	1.78
<u>Correlations</u>					
$corr(Y_i^*,Y_i)$	0.39	0.37	0.32	0.63	0.43
$corr(Y^*,Y)$	0.37	0.37	0.37	0.37	0.37
$corr(Y_i^*,Y^*)$	0.22	0.05	0.48	0.43	0.29
$corr(Y_i,Y)$	0.59	0.62	0.79	0.70	0.68
$corr(Y^*,W^*)$	0.79	0.79	0.79	0.79	0.79
$corr(Y,W)$	0.45	0.45	0.45	0.45	0.45

Notes:

The top half of the table shows standard deviations (in percent) for the production-worker wage bill in specific Mexico (Y_i^*) and U.S. outsourcing industries (Y_i), and in Mexico (Y^*) and U.S. (Y) aggregate manufacturing, and the ratios of these standard deviations. The bottom half of the table shows correlations between the wage-bill series, and between the wage bill and average hourly wage in manufacturing. Each series is in log real values (deflated by the national CPI), seasonally adjusted, and HP filtered. Data are monthly from 1996 through 2005.

Table 2:
Difference-in-Differences for Variation in Mexico and U.S. Outsourcing Industries

A: 1992:1 to 2005:4	Apparel	Electrical Machinery	Electronics	Transport Equipment
Constant	0.186	0.186	0.186	0.186
	(0.020)	(0.021)	(0.020)	(0.020)
Outsourcing Industry	0.445	0.259	0.387	0.577
	(0.127)	(0.049)	(0.076)	(0.197)
Mexico	1.306	1.306	1.306	1.306
	(0.253)	(0.252)	(0.251)	(0.244)
Outsourcing*Mexico	0.442	1.895	1.918	1.202
	(0.388)	(0.440)	(0.454)	(0.452)
R^2	0.110	0.174	0.178	0.137

B: 1996:1-2005:4				
Constant	0.186	0.186	0.186	0.186
	(0.019)	(0.020)	(0.020)	(0.020)
Outsourcing Industry	0.469	0.267	0.542	0.583
	(0.164)	(0.055)	(0.093)	(0.260)
Mexico	1.306	1.306	1.306	1.306
	(0.238)	(0.257)	(0.248)	(0.250)
Outsourcing*Mexico	0.418	1.886	1.763	1.196
	(0.372)	(0.455)	(0.444)	(0.494)
R^2	0.107	0.169	0.170	0.134

C: 1992:1-2005:4				
Constant	0.143	0.143	0.143	0.143
	(0.025)	(0.024)	(0.025)	(0.024)
Outsourcing Industry	0.413	0.274	-0.053	0.603
	(0.150)	(0.085)	(0.031)	(0.142)
Mexico	4.367	4.367	4.367	4.367
	(0.820)	(0.810)	(0.790)	(0.812)
Outsourcing*Mexico	-2.614	-0.391	-1.983	-0.629
	(0.915)	(1.091)	(0.908)	(1.066)
Outsourcing*Post NAFTA	0.042	-0.021	0.581	-0.034
	(0.231)	(0.101)	(0.103)	(0.293)
Mexico*Post NAFTA	-4.046	-4.046	-4.046	-4.046
	(0.822)	(0.817)	(0.797)	(0.812)
Outsourcing*Mexico*Post NAFTA	4.059	2.779	5.580	2.028
	(0.982)	(1.138)	(1.062)	(1.124)
R^2	0.212	0.243	0.265	0.228

Notes to Table 2:

Each column shows results for a regression of the squared deviation from the mean of the production-worker wage bill (times 1000) for a sample that includes a Mexico maquiladora industry, the corresponding U.S. industry, aggregate Mexican manufacturing, and aggregate U.S. manufacturing, over the indicated sample period. Regressors in parts A and B of the table include a constant, a dummy for whether observations pertain to an outsourcing industry (as opposed to aggregate manufacturing), a dummy for whether observations pertain to Mexico (as opposed to the United States), and the interaction of the outsourcing-industry and Mexico dummies. In part C, we add interactions of all regressors with a dummy for whether the year is 1996 or later (indicating the post-NAFTA period). The main effect for the post NAFTA variable is not shown. Standard errors are obtained through bootstrapping, using 1000 repetitions.

Table 3
Model Simulation: Endogenous Outsourcing

shocks:	all four shocks	home demand	foreign demand	home prod	foreign prod.
Standard devs. (%):					
$\sigma(Y^*_{os})$	5.14	2.92	1.32	0.28	3.94
$\sigma(Y_{os})$	2.16	1.93	0.72	0.17	0.48
$\sigma(Y^*)$	2.59	1.67	1.26	0.03	1.47
$\sigma(Y)$	2.23	2.18	0.20	0.12	0.01
$\sigma(Y^*_{os})/\sigma(Y_{os})$	2.38	1.51	1.82	1.69	8.24
$\sigma(Y^*)/\sigma(Y)$	1.16	0.76	6.21	0.26	117.09
$\dfrac{\sigma(\text{Y*os})/\sigma(\text{Yos})}{\sigma(\text{Y*})/\sigma(\text{Y})}$	2.05	1.98	0.29	6.42	0.07
correlations:					
*cor(Y*os,Yos)*	0.26	1.00	-1.00	-1.00	-1.00
cor(Y,Y)*	0.70	1.00	1.00	-1.00	1.00
*cor(Y*os,Y*)*	0.70	1.00	-1.00	1.00	1.00
cor(Yos,Y)	0.94	1.00	1.00	1.00	-1.00
cor(Y,W*)*	0.59	-1.00	1.00	-1.00	1.00
cor(Y,W)	0.17	1.00	-1.00	1.00	1.00

CES preferences, free entry of new firms.
Weightings on four shocks, respectively: 3.4, 8.2, 0.2, 1.9.
Calibration: σ=6, θ=0.88, θ^*=0.71, $\alpha = 0.24$, μ=1, ϕ=2, n=0.74, ϖ=0.0267, B=0.0087 (so $\overline{N}$=6), $\bar{z}$=0.20, $A(\bar{z})$=0.125, $A(0)$ = 0.2.

Table 4
Model Simulation: Translog Preferences

shocks:	all four shocks	home Demand	foreign demand	home prod	foreign prod.	endog OS all four
standard devs. (%):						
$\sigma(Y^*_{os})$	5.05	1.38	0.06	0.02	4.93	4.51
$\sigma(Y_{os})$	1.86	1.73	0.01	0.12	0.73	1.03
$\sigma(Y^*)$	5.12	2.60	0.18	0.03	4.39	2.25
$\sigma(Y)$	4.35	4.29	0.01	0.11	0.75	1.79
$\sigma(Y^*_{os})/\sigma(Y_{os})$	2.72	0.80	4.78	0.20	6.73	4.37
$\sigma(Y^*)/\sigma(Y)$	1.18	0.61	25.44	0.26	5.88	1.26
$\frac{\sigma(\mathrm{Y^*os})/\sigma(\mathrm{Yos})}{\sigma(\mathrm{Y^*})/\sigma(\mathrm{Y})}$	2.31	1.32	0.19	0.76	1.14	3.46
correlations:						
*cor(Y*os,Yos)*	0.61	1.00	1.00	1.00	1.00	-0.53
cor(Y,Y)*	0.66	1.00	1.00	1.00	1.00	0.58
*cor(Y*os,Y*)*	0.69	-1.00	-1.00	1.00	1.00	0.38
cor(Yos,Y)	-0.84	-1.00	-1.00	1.00	1.00	-0.83
cor(Y,W*)*	0.84	-1.00	1.00	1.00	1.00	0.74
cor(Y,W)	0.47	1.00	-1.00	1.00	1.00	0.51

Exogenously fixed outsourcing margin, free entry of new firms.
Weightings on the four shocks, respectively, in the first five columns: 15.0, 1.0, 0.2, 8.0; in the last column: 3.4, 8.2, 0.2, 1.9.

Calibration: σ=6, θ=0.88, θ^*=0.71, $\alpha = 0.24$, μ=1, ϕ=2, n=0.74, ϖ=0.0267, *B*=0.0087 (so $\overline{N}$=6), $\bar{z}$=0.20.

Figure 1: Industry Shares of Maquiladora Employment in Mexico

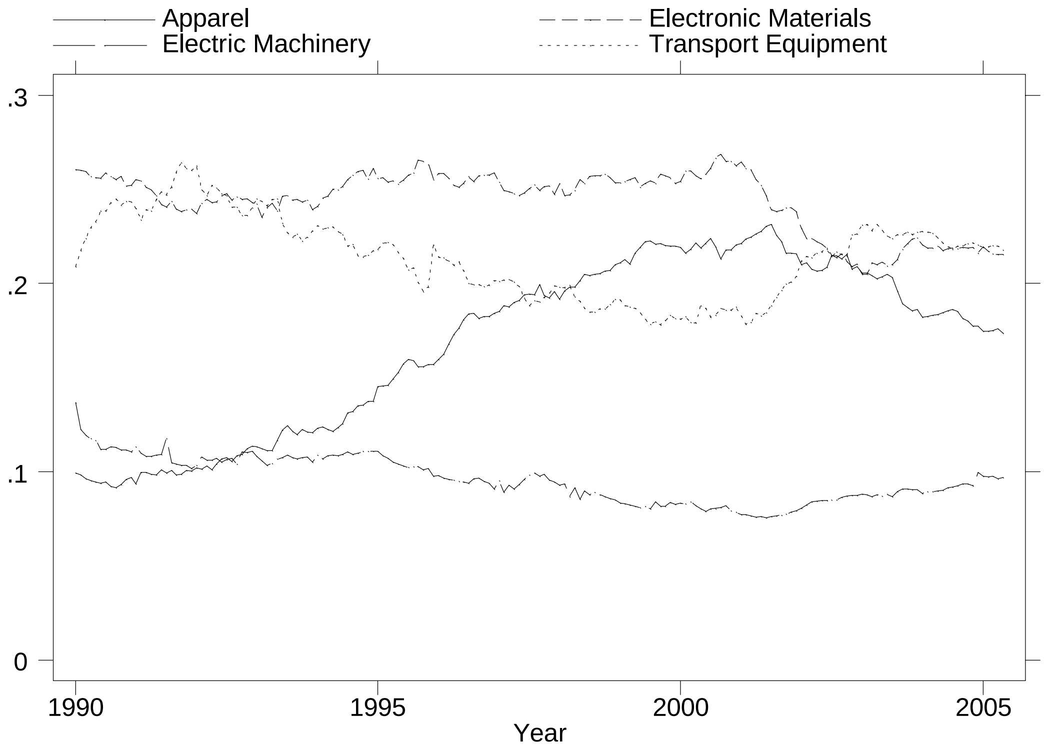

Figure 2: Maquiladora Activity in Mexico
(log values)

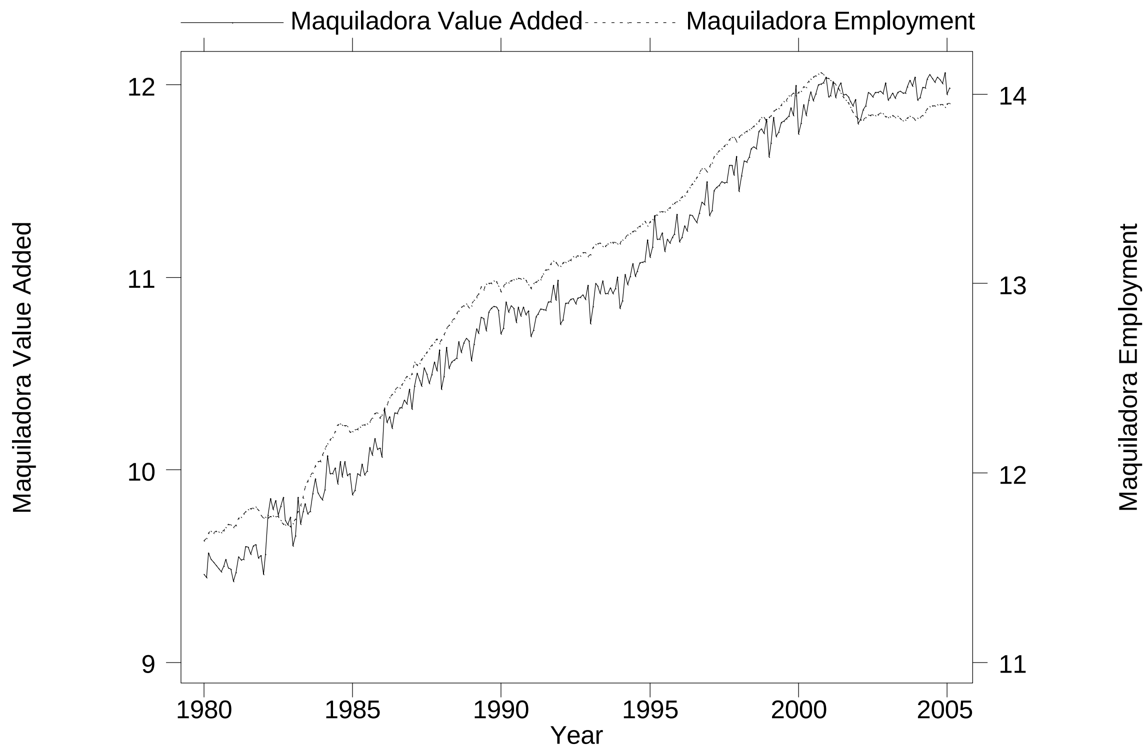

Figure 3: Wage Bill for Production Workers in Mexico and U.S. Outsourcing Industries
(log real values, seasonally adjusted and HP filtered)