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 among the first in the trade 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 a theoretical model of outsourcing that can explain this volatility. One novel feature of this model is an extensive margin in outsourcing, whereby U.S. firms respond to cyclical changes in sales by entering or exiting outsourcing relationships in Mexico. A second feature is the use of translog preferences to modulate firm entry, which implies that the fixed cost activities of management located in the U.S. exhibit lower volatility than the variable cost activities of assembly.

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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 E.U. and emerging economies in Europe, and in global trade with China. In Mexico, employment in outsourcing industries grew ten-fold from 0.12 million in 1980 to 1.2 million in 2005. The sector accounts for just under 3% of Mexico's total GDP, 20% of Mexican manufacturing value added, and nearly half of the country's exports. While Mexican officials have hailed the export assembly plants that engage in outsourcing for their contribution to economic growth, some have also complained that the sector is fickle and subject to excessive volatility.[1] The assembly plants, known as *maquiladoras*, are seen as a channel by which the U.S. exports to Mexico a portion of its employment fluctuations over the business cycle. Despite abundant literature on how global outsourcing affects the volume of trade, wage levels, and environmental regulation,[2] there is much less work on the implications of outsourcing for the variability of economic activity.[3] This paper aims to help fill this gap.[4]

We begin by documenting the variance in outsourcing industries in Mexico. These industries are composed of maquiladoras to which U.S. and other foreign firms outsource the assembly of inputs into final outputs. Our data cover Mexico's four largest outsourcing industries, which together

[1] See for example the news account of how the Mexican car industry is highly 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 and Feenstra and Hanson (2003) for a survey of the literature.
[3] Burstein, Kurz, and Tesar (2005) develop a dynamic model of trade in intermediate inputs in which trade flows between high-wage and low-wage countries (whose respective outputs are assumed to be complements in production) synchronizes business cycles among trading partners. One difference from our work is that they focus on international comovement and correlations, whereas we focus on relative volatilities. A second difference is that they model international production as the aggregation of home and foreign intermediate goods that are complements, whereas we model international production in terms of outsourcing of variable cost activities over a continuum of heterogeneous firms. For other work on in intermediate inputs and business cycle synchronization see Kose and Yi (2001) and Ambler, Cardia, and Zimmerman (2002).
[4] This paper focuses on understanding the positive aspects of outsourcing, and leaves the normative implications to future work.

account for three quarters of outsourcing production in the country: apparel, transportation equipment, electronics, and electrical machinery. We match these industries to their counterparts in the United States. Our main empirical result is that in all four outsourcing industries the volatility of economic activity in Mexico is significantly higher than in the U.S.; averaging over the four industries, volatility in Mexico is twice as high as in the U.S. One conjecture might be that this simply reflects higher volatility in the Mexican economy overall. While aggregate manufacturing in Mexico is more volatile than in the U.S., the gap is much less than that found between Mexican maquiladora industries and their U.S. counterparts. In a difference-in-difference regression, adapted for second moments, there is a statistically significant difference between Mexican and U.S. volatility in outsourcing industries, even after controlling for cross-country differences in aggregate manufacturing volatility. Another conjecture might be that higher volatility in Mexico reflects the smaller size of industries in Mexico. However, our results are robust to comparing Mexican industries with the more similarly sized industries of U.S. border states.[5]

To explain differential volatility in countries engaged in outsourcing, we develop a theoretical model of global production sharing that introduces two new mechanisms for generating volatility. The model relies 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 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 high-wage home country, representing headquarter and managerial costs, and a variable-

[5] A third conjecture might be that labor-market institutions differ between the countries, such that it is easier to hire and fire employees in Mexico. However, when Botero et al. (2004) rank countries in terms of job security laws restricting the hiring and firing of workers, Mexico ties for the most regulated among the 85 countries in the sample, whereas the U.S. ranks as the fifth least regulated economy in this respect; these data are used in the analysis of volatility and comparative advantage by Cunat and Melitz (2006). We also see this contrast in labor market flexibility reflected in our employment data discussed below, in which volatility of employment in overall Mexican manufacturing is lower than that for U.S. overall manufacturing.

cost activity representing assembly work that can be done at home or outsourced to a low-wage foreign country.

The first key feature of the model is that the point along the product continuum at which firms in the home country begin to outsource the variable-cost activity to firms in the foreign country is endogenously determined as firms compare the unit labor costs across borders.[6] When the home country experiences a boom in demand, the fact that wages in the country tend to be procyclical alters the outsourcing decision of some firms. If home workers become relatively more expensive to hire, firms that previously had not outsourced any production now find it profitable to do so. This shift in the extensive margin acts as a powerful mechanism for the international transmission of shocks, whereby U.S. producers shift unusually high levels of production abroad during a domestic economic boom, and the reverse during a recession. 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 outsourcing industries in the low-wage foreign country than on the domestic counterpart industries. Volatility is higher in the foreign country, owing to the fact that firms there specialize entirely in the variable-cost activity.

A second novel feature of the model is the use of preferences obtained from a translog expenditure function, which has the convenient property that the elasticity of demand for each product variety is proportional to the number of firms in the industry.[7] As a result, markups charged by firms are countercyclical, and stochastic increases in demand are not fully absorbed by new entrants; rather, increases in demand are split between entry of new firms and increases in firm size.[8] Because countercyclical markups dampen the entry of new firms, the fixed-cost activity fluctuates

[6] 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.

[7] 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.

[8] 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.

less than the variable-cost activity. Through outsourcing, the higher volatility in the variable-cost activity translates into higher volatility in production for the low-wage foreign country.

The outsourcing sector is embedded in a two country, general equilibrium trade model, which also includes an undifferentiated traded good in each country. Analytical results show how both of our new mechanisms affect the relative volatility in the industry wage bill across the two countries in the outsourcing sector. Numerical examples, by way of stochastic simulation under demand and supply shocks, indicate that the two mechanisms together can provide a reasonable explanation for the extra volatility in Mexican outsourcing. The results also indicate that among the two new model features, it is the endogeneity of the extensive margin in outsourcing that is the more potent in accounting for differential volatility in U.S. and Mexican outsourcing industries.

The next section presents the data and empirical results. Section 3 presents the theoretical model, and section 4 discusses theoretical results.

II. Data and Empirical Results

Outsourcing by the U.S. 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 plants – the maquiladoras – tend to specialize in assembly services.[9] Mexico is among the most important locations for global outsourcing by U.S. firms and the U.S. 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

[9] 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.)

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).[10] 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 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

[10] 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).

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; the wage bill for production workers, which is a substantial component of value added; employment of production workers; and total employment.[11] 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). Data are available from 1993 forward.[12] However, in late 1994 there was a large depreciation of the peso, as

[11] 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%.
[12] Data for Mexico's maquiladora industries go back to 1990. However, data on Mexico's overall manufacturing sector is only available from 1993 forward, owing to a change in the construction of the series in that year.

capital fled Mexico, and in 1995 output dropped sharply. Given the exposure of the maquiladora sector to exchange-rate fluctuations, including the peso-crisis years in our sample could make volatility in Mexico's outsourcing industries seem artificially high. To avoid this problem, we limit the analysis to the period 1996-2005.

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 1A, which shows the ratio of the standard deviations for the wage bill in Mexican and U.S. industries, reinforces this perception. In each industry, the standard deviation of Mexican earnings is greater than in the United States, with the Mexico-U.S. ratio averaging 2.03 over the four industries.

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 1A also shows the relative standard deviation in the industry wage bill in the two countries divided by the relative standard deviation for the production-worker wage bill for all manufacturing industries. While overall manufacturing earnings in Mexico are more volatile than in the U.S., the relative volatility of Mexico's maquiladora industries is even greater. The Mexico-U.S. standard-deviation ratio, divided by the aggregate manufacturing standard-deviation ratio, averages 1.3 over the four outsourcing industries.

For robustness, Table 1B reports the same standard deviations and ratios for production worker employment rather than the wage bill. The contrast in outsourcing volatility stands out even more clearly here. This is mainly due to the fact that volatility in overall manufacturing employment in Mexico is low relative to the U.S. This may reflect the finding in Botero et al. (2004) that Mexico has more restrictive laws regarding employment security (see note 5).

Another potential 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 be larger than for the U.S. simply because summing over a larger number of plants in the United States tends to smooth out shocks that are idiosyncratic to plants. Table 2 reports production worker employment in each industry, showing that in two of the four industries the U.S. is indeed much larger. One option to deal with potential size disparities would be to use more narrowly defined industry categories in the U.S. But if we were to move to four-digit classifications, the composition of goods in the U.S. and Mexican industries would differ, making it difficult to draw reasonable comparisons.[13] An alternative way of dealing with potential size disparities is to reduce the geographic coverage of the U.S. series. The vast majority of maquiladoras in Mexico are located in Mexican border cities and many are linked to production operations on the U.S. side of the border (Feenstra, Hanson, and Swenson, 2000). This makes U.S. border states a natural geographic unit to which to compare Mexican outsourcing industries. In Table 3, we compare Mexican industries to their counterparts in California and Texas, which are the two U.S. border states for which industry data are available.[14] At the state level, the only series available for three-digit industries is total employment. Table 2 shows that employment in outsourcing industries in California and Texas is similar in scale to Mexican industries. Table 3 shows that that standard deviations and their ratios based on state employment data are very similar to those obtained for national data.

To examine in a more formal manner the relative volatility of Mexican and U.S. outsourcing industries, 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

[13] In unreported results, we examined relative volatilities in Mexican industries and their corresponding U.S. four-digit industries. The results are qualitatively very similar to those reported in Tables 1, 3 and 4.

[14] The small number of plants in three-digit manufacturing industries in Arizona and New Mexico makes industry-level data for these states subject to disclosure restrictions.

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 and time. Then, we add to this sample pooled observations on $(Y_{ict} - \overline{Y}_{ic})^2$ 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:

$$(Y_{ict} - \overline{Y}_{ic})^2 = b_0 + b_1 1[i=o] + b_2 1[c=MX] + b_3 1[i=o]1[c=MX] + e_{ict}$$

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 e_{ict} is a disturbance term discussed below.

The regression equation is a difference-in-difference estimator of the variability of industry activity. The coefficient ß$_3$ 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, ß$_2$) and differences in variability between outsourcing industry o and aggregate manufacturing (captured by the main effect on the outsourcing industry dummy, ß$_1$). 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. The sample period for the analysis is 1996:1-2005:12.

In Table 4A, we see that the variability of the wage bill in Mexico's outsourcing industries is higher than in corresponding U.S. industries, even after controlling for the binational difference in variability for aggregate manufacturing. For all four industries, 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). Table 4B shows that the results are essentially the same when the methodology is applied to state-level employment data. For all industries and cases tested, the interaction term is positive and strongly statistically significant. These results indicate 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.).

III. Theoretical Model

A. Pricing and Product Variety in the Outsourcing Sector

In this section we develop a theoretical model of outsourcing which can broadly replicate the empirical finding documented above, and which can help us understand how outsourcing generates amplified volatility in a country like Mexico. 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*. 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.

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 $a_{Mt}(z) = \exp(az + b_t)$ in the home country. The foreign country has a corresponding distribution, and the relative unit cost function between the two countries will be specified:

$$A(z) = \frac{a_{Mt}(z)}{a_{Mt}^{*}(z)} = \frac{\exp(az + b_t)}{\exp(a^{*}z + b_t^{*})} = \exp(a_d z + b_{dt})$$

The share of outsourcing varieties z'_t, is determined by the relative wages across countries (W_t and W_t^{*})

$$A(z'_t) = \frac{W_t^{*}}{W_t} \qquad (1)$$

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

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

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 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 were to make the usual assumption of a CES specification of preferences over entrants within a variety with elasticity s, the number of entrants will be

$$N_{CES,t} = \frac{D_{Mt} + D^*_{Mt}\left(\frac{1-n}{n}\right)}{s\,BW_t}. \tag{3}$$

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).

Instead, we will focus on a case where preferences over varieties that are not CES. A particularly useful and tractable specification for preferences in this case are those that follow a translog form, where the unit-expenditure function over the varieties of each product z is

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

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

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

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":

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

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).

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:

$$L_{CES,Mt} = \left(\frac{D_{Mt} + D^*_{Mt}\left(\frac{1-n}{n}\right)}{s\,W_t} \right)\left(1 + (s-1)(1 - z'_t)\right)$$

$$\left(\frac{1-n}{n}\right) L^*_{CES,Mt} = \left(\frac{D_{Mt} + D^*_{Mt}\left(\frac{1-n}{n}\right)}{W^*_t} \right)\left(\frac{s-1}{s}\right) z'_t \qquad (7a,b)$$

For translog preferences:

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

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

B. Production in the Rest of the Economy

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

$$Y_{Ht} = \frac{L_{Ht}}{a_{Ht}}, \qquad (9)$$

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

$$W_t = \frac{p_{Ht}}{a_{Ht}} \qquad (10)$$

Where p_{Ht} is the relative price of the home domestic good in terms of the multinational good numeraire. Analogous conditions apply to the foreign country's undifferentiated good.

C. Households

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:

$$\max \quad E_0 \sum_{t=0}^{\infty} b^t \left(\frac{1}{1-f} C_t^{1-f} - \frac{1}{1+m} L_t^{1+m} \right)$$

$$st. \quad P_{Ht} C_{Ht} + P_{Ft} C_{Ft} + C_{Mt} + \sum_{s^{t+1}} v\left(s^{t+1} \mid s^t\right) X\left(s_{t+1}\right) = W_t L_t + X_t$$

$$where \quad C_t = \left((1-a)^{\frac{1}{c}} \left(q^{\frac{1}{h}} C_{Ht}^{\frac{h-1}{h}} + (1-q)^{\frac{1}{h}} C_{Ft}^{\frac{h-1}{h}} \right)^{\frac{h}{h-1}\frac{c-1}{c}} + a^{\frac{1}{c}} \left(C_{Mt}\right)^{\frac{c-1}{c}} \right)^{\frac{c}{c-1}}$$

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 imply the following risk-sharing condition equating the marginal utilities of consumption up to a constant of proportionality

$$\frac{P_t C_t^f}{P^*_t C_t^{*f}} = w \,, \tag{11}$$

where w 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:

$$\frac{C_{Mt}}{C_{Ht}} = \left(\frac{a}{q\,(1-a)} \right) P_{Ht} \tag{12}$$

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

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

$$\frac{L_t^m}{W_t} = q\,(1-a)\frac{C_t^{1-f}}{P_{Ht} C_{Ht}} . \tag{14}$$

Corresponding conditions apply for the foreign country.

An exogenous component of demand will be denoted G_t. This term is introduced to capture changes in demand exogenous to the model, such as shifts in government purchases and investment demand. The exogenous demand is allocated among the three goods in the same way as private consumption, according to demand conditions like (12 and 13) above. Denote total demands as the sum of consumption and exogenous demand: $D_t = C_t + G_t$, $D_{Mt} = C_{Mt} + G_{Mt}$, etc.

D. Market Clearing and Equilibrium

The market clearing condition for the 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), and the normalization of the price of the numeraire good D_{Mt} (as described in the Appendix).

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

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

E. Shocks

The model will include shocks both to demand and supply, entering through the additive demand term (G_t and G_t^*) and the unit labor cost terms (a_{Ht} and a_{Ft}^*). Both types of shocks are specified as first order autoregressions in log deviations from their respective means:

$$\begin{bmatrix} \log(a_{Ht}) - \log(\overline{a_H}) \\ \log(a_{Ft}) - \log(\overline{a_F}) \end{bmatrix} = r_a \begin{bmatrix} \log(a_{Ht-1}) - \log(\overline{a_H}) \\ \log(a_{Ft-1}) - \log(\overline{a_F}) \end{bmatrix} + \begin{bmatrix} e_{aHt} \\ e_{aFt} \end{bmatrix}, \text{ where } \begin{bmatrix} e_{aHt} \\ e_{aFt} \end{bmatrix} \sim \text{N}\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, s_a \right)$$

and:

$$\begin{bmatrix} \log(G_t) - \log(\overline{G}) \\ \log(G^*_t) - \log(\overline{G^*}) \end{bmatrix} = r_G \begin{bmatrix} \log(G_{t-1}) - \log(\overline{G}) \\ \log(G^*_{t-1}) - \log(\overline{G^*}) \end{bmatrix} + \begin{bmatrix} e_{Gt} \\ e_{G^*t} \end{bmatrix}, \text{ where } \begin{bmatrix} e_{Gt} \\ e_{G^*t} \end{bmatrix} \sim \text{N}\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, s_G \right).$$

IV. Model Results

A. Analytical result

This section demonstrates that the model can broadly replicate the primary empirical result in section 2, which is amplified volatility in the outsourcing sector of the foreign country. It then analyzes the model features most important for generating this result.

Some useful intuition into the relative volatility across countries in the outsourcing 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:

$$\frac{Y_{Mt}^{*}}{Y_{Mt}} = \frac{W_t^{*} L_{CES,Mt}^{*}}{W_t L_{CES,Mt}} = \frac{\left(\frac{n}{1-n}\right)\left(D_{Mt} + \left(\frac{1-n}{n}\right) D_{Mt}^{*}\right)\left(\frac{s-1}{s}\right) z'_t}{\left(\frac{D_{Mt} + \left(\frac{1-n}{n}\right) D_{Mt}^{*}}{s}\right)\left(1+(s-1)(1-z'_t)\right)} = \frac{(s-1) z'_t}{1+(s-1)(1-z'_t)}\left(\frac{n}{1-n}\right). \quad (18)$$

Note that if the outsourcing share (z) were modeled as an exogenous constant, then the ratio above also would be a constant, and value added across countries would be directly proportional to each other. In other words, the percentage volatility of earnings in the outsourcing sectors in the two countries necessarily would be equal to each other.

This result might 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 tight linkage. First, we can allow the outsourcing margin to be endogenous, so that the term z' in equation (18) above varies, thus allowing the ratio of income on the left side of that equation also to vary over time. For example, consider a rise in overall demand in the home country. If this drives up relative wages in the home country, it will induce some firms previously near the margin to begin outsourcing. This direct shift in employment for variable cost activities from the home to the foreign country will reduce the impact of the demand shock on employment and labor earnings in the home country, and act as a mechanism to transfer some of the impact of the demand shock to the foreign outsourcing sector. Depending on how sensitive firms are in the outsourcing sector of the U.S. to relative wage changes, and depending on the prevalence of U.S. demand shocks, this is a potential mechanism for reducing volatility in the U.S. outsourcing sector and raising it in the corresponding sector in Mexico. In other words, even if Mexico has restrictions on the ability of firms to fire and hire workers, if U.S. firms are able to enter and exit outsourcing relationships with Mexican firms, this becomes a mechanism by which U.S. firms can shunt temporary excess demand off on foreign production facilities, and vice versa during temporary shortfalls in demand.

The second approach used in the paper for breaking the link between countries in the outsourcing sector is 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. As discussed above, introducing translog preferences in the model is one way to implement this feature. When a rise in demand encourages new entry, the resulting rise in substitution elasticity and resulting fall in markups lowers profits, thereby discouraging entry. As a result, aggregate earnings by workers in the fixed-cost activity of the outsourcing sector in the home country varies less in response to fluctuations in demand than does the variable cost activity.

B. Calibration of Numerical Experiment

A numerical experiment is helpful for evaluating the model's ability to generate volatility in the outsourcing sector. Parameter calibrations are summarized in Table 5.

The U.S. unit cost distribution in the outsourcing sector is characterized by the two parameters b and a. The first can be calibrated by requiring that the cost at the margin be the same as for the overall U.S. manufacturing sector (that is, set $a_M\left(\bar{z}\right) \equiv \exp\left(a\bar{z} + b_t\right) = \overline{a_H}$). The second parameter can be pinned down using the observation in Bernard et al. (2003) that the standard deviation of log U.S. plant sales is 1.67.[15] The value of $\bar{z}$ then is calibrated at 0.2, to match the Mexican share of employment in the data for the four outsourcing industries.

Similarly, two pieces of information are needed to pin down the two parameters a_d and b_d in the cross-country relative unit cost distribution, $A\left(z_t\right) = \exp\left(a_d z_t + b_{dt}\right)$. First, the average weekly rate of payment to workers for the four outsourcing industries in the data set is 8 times higher in the U.S. than in Mexico, implying that $A\left(\bar{z}\right)$=1/8 and hence $b_d = \log\left(0.125\right) - a_d \bar{z}$. Unfortunately there is no information on the standard deviation of the relative unit cost distribution analogous to that used above for the U.S. cost distribution. Of special significance for the endogenous outsourcing mechanism is the slope of the distribution at the steady state margin of outsourcing, $A'\left(\bar{z}\right) \equiv \partial \ln A\left(z\right) / \partial \ln z$ evaluated at $z = \bar{z}$. The flatter the distribution at this point, the stronger will be the adjustment in the outsourcing margin for a given relative wage change. To gauge the potential impact of the outsourcing margin, we begin by calibrating this slope to be near zero ($A'\left(\bar{z}\right) = -0.001$), and then conduct sensitivity analysis for alternative calibrations.[16]

The size of the fixed cost of entry in the outsourcing sector (*B*) is calibrated so that in steady state each industry has 6 firms. This implies an elasticity of substitution of 6 and markups of 20%.

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15 In particular, given that the distribution is defined over the unit interval, the constant value *a* can be computed as $1.67(1/12)^{-0.5}/s$, and b_t varies with overall productivity shocks $b_t = \log(a_{Ht}) - a\bar{z}$.

16 Note that the relative unit cost distribution parameters are not time-varying, which implies that productivity shocks in one country's outsourcing sector are transmitted fully to foreign counterparts producing the same good, so that the ratio of the unit costs across countries is unaffected. An alternative assumption would be to shift the A(z) distribution in proportion to productivity shocks in either country. In experiments, this was found to imply a strongly negative correlation in the output levels of the outsourcing sectors across countries, which is counterfactual. Our maintained assumption that productivity shocks are transmitted fully to foreign affiliates is very similar to that assumed in Burstein, et al (2005), also used to generate positive cross-country correlations in a model of multi-national production.

Regarding preference parameters, calibrations for the most standard of these are taken from the business cycle literature. The labor supply elasticity is set at unity, $m=1$. The curvature parameter is set at $f=2$. The elasticity of substitution between home and foreign goods is calibrated at the common value of unity ($h=1$). Since the multinational good can be produced either as a home or as a foreign good, we assume that it has a higher elasticity ($c=2$).

The remaining preference parameters are calibrated to reflect the relationship between U.S. and Mexican aggregates in 2003. The home bias parameters reflect the share of import expenditures in GDP, $q=0.88$, $q^*=0.71$. 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 at $a=0.24$. The relative weight on the home country in the complete asset market allocation (v) is calibrated to replicate the ratio of U.S. to Mexican per capita consumption. The steady state level of the additive demand terms ($\overline{G}$ and $\overline{G^*}$) are calibrated at 1/3 of total demand, so that private consumption represents 2/3 of overall demand. The U.S. population represents 74 percent of the total population of the two countries combined.

Productivity shock parameters are estimated from a first-order autoregression on Solow residuals, computed from HP-filtered monthly manufacturing data.[17] Regarding demand shocks, since there is no monthly series available for government consumption, total government spending from IFS is used. See Table 5 for exact values.

C. Numerical Results

Simulations consist of solving the model numerically in its original nonlinear form for 120 periods of random draws of shocks. The first 20 periods are dropped, and the remaining 100 periods

[17] We follow the convention in Glick and Rogoff (1995) of computing Solow residuals by setting the labor share at 0.6 and assuming a constant capital stock. Resulting estimates are almost identical if we assume a labor share of unity, as implied by the production function in the model above.

are HP filtered and deflated by the CPI, just as were the data reported in Table 3, and used to compute moments. This process is repeated 1000 times, and we report the average of moments over the replications.

Table 6 reports results for the benchmark model. Although the focus of our study is on the outsourcing sector, it is reassuring for our general calibration of shocks that the volatilities for overall manufacturing income are in the neighborhood of what is observed in the aggregate data, although the U.S. volatility is somewhat high in the simulation. Of primary interest is the fact that the calibrated model does a remarkably good job of replicating the relative amplification of volatility in the outsourcing sectors of the two countries. While the data imply that outsourcing income is twice as volatile in Mexico as in the U.S., the model can explain why it is 78% more volatile. Regarding correlations, all are positive as in the data. The outsourcing model implies high cross-country correlation, both at the aggregate level and for outsourcing industries.[18] The subsequent columns of the table indicate that the US demand shocks and Mexican supply shocks are the primary drivers of these second moments.

Table 7 investigates sensitivity of results to the calibrated slope of the relative cost distribution. The benchmark assumption of a flat distribution in the neighborhood of the steady state clearly amplifies the relative volatility in the outsourcing sector. While this amplification decreases for steeper slopes, it remains substantial for a wide range of calibration values.

Next we investigate the relative contributions of the two key model features, endogenous outsourcing and translog preferences. Table 8 shows that when the outsourcing margin is held fixed, the translog preferences on their own generate significantly less amplification, albeit still a positive amount. The potency of translog preferences to make Mexican volatility more volatile than in the

[18] The high cross-country correlation is both due to the endogenous outsourcing mechanism and the presence of demand shocks. When the outsourcing mechanism is removed (a =0 and z' fixed at $\bar{z}$), the aggregate income correlation falls from 0.91 to 0.72. When demand shocks are eliminated as well as outsourcing, the correlation falls to 0.16.

U.S. is limited by the size of the fixed cost activity in the U.S. The fixed cost parameter, *B*, is calibrated to imply an endogenous elasticity of substitution of 6; in the present model, this calibration implies the size of the fixed cost activity is approximately 10% of employment in the U.S. outsourcing sector. When translog preferences are replaces with CES, the endogenous outsourcing mechanism on its own generates only a slightly smaller standard deviation in the Mexican outsourcing sector than in the benchmark case. When both translog preferences and endogenous outsourcing are shut down, volatility in the outsourcing sector is strongly reduced.[19]

The theory does not attempt to model the complex dynamics of firm entry, in which it is reasonable to think there are substantial delays between a decision to enter and actually commencing production. Nor does the theory model the sunk cost of entry, which might discourage entry in response to transitory shocks. We test whether the modeling of this feature could be quantitatively relevant for the issue at hand, by modeling it in its most extreme form. Column 6 of Table 8 reports simulation results for the case where no new firm is able to enter. The results show that precluding entry only raises by a small amount the ratio of outsourcing volatility in Mexico compared to the U.S. Since modeling the most extreme form of sluggishness in firm entry has a quantitatively small impact on the results, it would seem that modeling the intermediate cast of realistic entry dynamics, which would require an entirely new model solution methodology, is not warranted.

V. Conclusion

This paper has studied the second-moment properties of global outsourcing. It has documented a new empirical regularity: outsourcing industries in Mexico experience fluctuations in economic activity that are twice as volatile as the corresponding industries in the U.S. A difference-in-

[19] The fact there is any extra volatility in Mexican outsourcing relative to the U.S. in this case is due entirely to relative movements in the CPIs used to deflate the variables before computing moments. Simulation results confirm the theoretical prediction earlier in the paper, that when income is reported in units of goods and not deflated to consumption units, the ratio of standard deviation in Mexican outsourcing to that in the U.S. is precisely unity.

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 empirical regularity. A potential extension in future research would be to generalize the model to include the dynamics of investment in real capital.

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Appendix

In addition to 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:

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

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

$$h_{it}(z) = 1 - \frac{\partial \ln s_{it}(z)}{\partial \ln p_{it}(z)} = 1 - \frac{g_{ii}}{s_{it}(z)}. \qquad \text{(A2)}$$

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:

$$h_{it}(z) = 1 + g[N_t(z) - 1]. \qquad \text{(A3)}$$

With the added parameter restriction that g = 1, then we see that $h_{it}(z) = N_t(z)$, 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 s, thereby obtaining profits $[D_{Mt} + D^*_{Mt}(1-n)/n]/[sN_t(z)]$. 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

$h_{it}(z) = N_t(z)$, 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 $a_{Mt}(z)y_t(z)$ for those products $z \in [z'_t, 1]$:

$$L_t = \int_0^1 BN_t dz + \int_{z'_t}^1 a_{Mt}(z)y_t(z)N_t dz\,. \tag{A4}$$

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 $s/(s-1)$ 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 $[D_{Mt} + D^*_{Mt}(1-n)/n](s-1)/sW_t$, 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 $h_t/(h_t - 1) = N_t/(N_t - 1)$, 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 $a^*_{Mt}(z)y^*_t(z)$ for $z \in [0, z'_t]$:

$$L^*_t = \int_0^{z'_t} a^*_{Mt}(z)y^*_t(z)N_t dz\,. \tag{A5}$$

Multiplying the labor costs $a^* y^*_t(z)$ by the wage W^*_t, and further multiplying by the markup $s/(s-1)$ 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 $[D_{Mt} + D^*_{Mt}(1-n)/n](s-1)/sW^*_t$, 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 $h_t/(h_t - 1) = N_t/(N_t - 1)$, 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:

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

and alternatively in the translog case:

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

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

Table 1A. Relative Volatility in Mexico and U.S. Outsourcing Industries: Production Worker Wage Bill

	Apparel	Electrical Machinery	Electronics	Transport Equipment	Average
Standard Deviations					
$s(Y_i^*)$ (Mex. Outsourcing Industry)	4.83	4.41	6.21	4.20	4.91
$s(Y_i)$ (U.S. Outsourcing Industry)	2.31	2.01	2.79	2.63	2.44
$s(Y^*)$ (Mex. Aggregate Manufacturing)	1.94	1.94	1.94	1.94	1.94
$s(Y)$ (U.S. Aggregate Manufacturing)	1.27	1.27	1.27	1.27	1.27
$s(Y_i^*)/s(Y_i)$	2.09	2.19	2.23	1.60	2.03
$s(Y^*)/s(Y)$	1.53	1.53	1.53	1.53	1.53
$\frac{s(Y_i^*)/s(Y_i)}{s(Y^*)/s(Y)}$	1.37	1.44	1.46	1.05	1.33
Correlations					
$corr(Y_i^*, Y_i)$	0.24	0.29	0.51	0.41	0.36
$corr(Y^*, Y)$	0.24	0.24	0.24	0.24	0.24
$corr(Y_i^*, Y^*)$	0.33	0.48	0.47	0.15	0.36
$corr(Y_i, Y)$	0.52	0.75	0.57	0.63	0.62

Notes:
The top half of the table shows standard deviations (in percent) for the production-worker wage bill in specific Mexico and U.S. outsourcing industries, and in Mexico and U.S. aggregate manufacturing, and the ratios of these standard deviations. Each series is in log real values (deflated by the national CPI), seasonally adjusted, and HP filtered. Data are monthly from 1996 through 2005.
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 1B. Relative Volatility in Mexico and U.S. Outsourcing Industries: Production Worker Employment

	Apparel	Electrical Machinery	Electronics	Transport Equipment	Average
Standard Deviations					
$s(Y_i^*)$ (Mex. Outsourcing Industry)	4.52	4.34	5.95	2.96	4.44
$s(Y_i)$ (U.S. Outsourcing Industry)	1.89	1.79	3.06	1.42	2.04
$s(Y^*)$ (Mex. Aggregate Manufacturing)	0.89	0.89	0.89	0.89	0.89
$s(Y)$ (U.S. Aggregate Manufacturing)	1.15	1.15	1.15	1.15	1.15
$s(Y_i^*)/s(Y_i)$	2.39	2.42	1.94	2.08	2.21
$s(Y^*)/s(Y)$	0.77	0.77	0.77	0.77	0.77
$\frac{s(Y_i^*)/s(Y_i)}{s(Y^*)/s(Y)}$	3.09	3.13	2.51	2.69	2.86
Correlations					
$corr(Y_i^*, Y_i)$	0.49	0.43	0.66	0.45	0.51
$corr(Y^*, Y)$	0.78	0.78	0.78	0.78	0.78
$corr(Y_i^*, Y^*)$	0.56	0.71	0.62	0.68	0.64
$corr(Y_i, Y)$	0.66	0.86	0.88	0.63	0.76

The table follows the same format as Table 1A, replacing the standard deviation of the production-worker industry wage bill with that for production worker employment.

Table 2. Size of Outsourcing Industries in Mexico and the U.S.

		Thousands of employees (mean 2000-2005)			
NAICS	Industry	Mexico	US	Texas	California
	All maquiladoras (Mex.)	1,151.00	--	--	--
	All manufacturing (U.S.)	--	15,336.70	955.5	1,649.00
315	Apparel	230.8	356.9	--	97.4
334	Electronic materials	265.6	1,512.30	132.9	366.6
335	Electrical machinery	100.2	497.5	20.0	38.5
336	Transport equipment	240.7	1,855.80	85.2	137.5

Table 3. Relative Volatility in Mexico and U.S. Outsourcing Industries: Total Employment at the U.S. State Level

	Apparel	Electrical Machinery	Electronics	Transport Equipment	Average
			National Level		
$\sigma(Y_i^*)$ (Mex. Outsourcing Industry)	4.48	4.11	5.50	2.73	4.21
$\sigma(Y_i)$ (U.S. Outsourcing Industry)	1.63	1.52	2.47	1.07	1.67
$\sigma(Y^*)$ (Mex. Aggregate Manufacturing)	0.77	0.77	0.77	0.77	0.77
$\sigma(Y)$ (U.S. Aggregate Manufacturing)	1.01	1.01	1.01	1.01	1.01
$\sigma(Y_i^*)/\sigma(Y_i)$	2.75	2.70	2.23	2.55	2.56
$\sigma(Y^*)/\sigma(Y)$	0.76	0.76	0.76	0.76	0.76
$\frac{\sigma(Y_i^*)/\sigma(Y_i)}{\sigma(Y^*)/\sigma(Y)}$	3.61	3.55	2.92	3.35	3.35
			California		
$\sigma(Y_i^*)$ (Mex. Outsourcing Industry)	4.48	4.11	5.50	2.73	4.21
$\sigma(Y_i)$ (U.S. Outsourcing Industry)	2.25	2.35	2.62	1.31	2.13
$\sigma(Y^*)$ (Mex. Aggregate Manufacturing)	0.77	0.77	0.77	0.77	0.77
$\sigma(Y)$ (U.S. Aggregate Manufacturing)	1.40	1.40	1.40	1.40	1.40
$\sigma(Y_i^*)/\sigma(Y_i)$	1.99	1.75	2.10	2.08	1.98
$\sigma(Y^*)/\sigma(Y)$	0.55	0.55	0.55	0.55	0.55
$\frac{\sigma(Y_i^*)/\sigma(Y_i)}{\sigma(Y^*)/\sigma(Y)}$	3.62	3.18	3.82	3.79	3.60
			Texas		
$\sigma(Y_i^*)$ (Mex. Outsourcing Industry)	4.48	4.11	5.50	2.73	3.09
$\sigma(Y_i)$ (U.S. Outsourcing Industry)	--	2.48	3.12	1.66	2.42
$\sigma(Y^*)$ (Mex. Aggregate Manufacturing)	0.77	0.77	0.77	0.77	0.77
$\sigma(Y)$ (U.S. Aggregate Manufacturing)	1.16	1.16	1.16	1.16	1.16
$\sigma(Y_i^*)/\sigma(Y_i)$	--	1.66	1.76	1.64	1.69
$\sigma(Y^*)/\sigma(Y)$	--	0.66	0.66	0.66	0.66
$\frac{\sigma(Y_i^*)/\sigma(Y_i)}{\sigma(Y^*)/\sigma(Y)}$	--	2.50	2.66	2.48	2.54

The table follows the same format as Table 1A, replacing the standard deviation of the production-worker industry wage bill with that for total employment.

Table 4A. Difference-in-Differences for Variation in Mexico and U.S. Outsourcing Industries Production Worker Wage Bill

	Apparel	Electrical Machinery	Electronics	Transport Equipment
Constant	**0.161**	**0.161**	**0.161**	**0.161**
	(0.021)	(0.020)	(0.020)	(0.021)
Outsourcing Industry	**0.370**	**0.240**	**0.613**	**0.526**
	(0.126)	(0.049)	(0.105)	(0.201)
Mexico	**0.211**	**0.211**	**0.211**	**0.211**
	(0.046)	(0.045)	(0.047)	(0.045)
Outsourcing*Mexico	**1.574**	**1.315**	**2.841**	**0.852**
	(0.294)	(0.232)	(0.475)	(0.319)
R Squared	0.224	0.246	0.234	0.110

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 period 1996:1-2005:12. Regressors 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. Standard errors are obtained through bootstrapping, using 1000 repetitions.

Table 4B. Difference-in-Differences for Variation in Mexico and U.S. Outsourcing Industries
U.S. State Level Total Employment

	Apparel	Electrical Machinery	Electronics	Transport Equipment
		National Level		
Constant	**0.101**	**0.101**	**0.101**	**0.101**
	(0.013)	(0.013)	(0.014)	(0.013)
Outsourcing Industry	**0.161**	**0.127**	**0.505**	**0.013**
	(0.034)	(0.035)	(0.096)	(0.030)
Mexico	**-0.043**	**-0.043**	**-0.043**	**-0.043**
	(0.016)	(0.016)	(0.016)	(0.016)
Outsourcing*Mexico	**1.767**	**1.492**	**2.441**	**0.668**
	(0.237)	(0.205)	(0.505)	(0.150)
R Squared	0.282	0.261	0.164	0.108
		California		
Constant	**0.195**	**0.195**	**0.195**	**0.195**
	(0.031)	(0.031)	(0.031)	(0.032)
Outsourcing Industry	**0.307**	**0.353**	**0.484**	**-0.024**
	(0.075)	(0.098)	(0.110)	(0.041)
Mexico	**-0.137**	**-0.137**	**-0.137**	**-0.137**
	(0.032)	(0.033)	(0.032)	(0.033)
Outsourcing*Mexico	**1.620**	**1.266**	**2.462**	**0.705**
	(0.239)	(0.220)	(0.495)	(0.152)
R Squared	0.249	0.209	0.158	0.093
		Texas		
Constant		**0.134**	**0.134**	**0.134**
		(0.015)	(0.014)	(0.015)
Outsourcing Industry		**0.474**	**0.832**	**0.141**
		(0.090)	(0.120)	(0.053)
Mexico		**-0.075**	**-0.075**	**-0.075**
		(0.017)	(0.016)	(0.017)
Outsourcing*Mexico		**1.145**	**2.113**	**0.540**
		(0.226)	(0.504)	(0.155)
R Squared		0.219	0.157	0.090

Each column shows results for a regression of the squared deviation from the mean of total employment (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 period 1996:1-2005:12. Regressors 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. Standard errors are obtained through bootstrapping, using 1000 repetitions.

Table 5. Calibration of model Parameters

<u>Preferences</u>

s	elasticity between varieties	6
c	elasticity between outsourcing and non-outsourcing goods	2
h	elasticity between home and foreign goods	1
q	home bias in U.S.	0.88
q^{*}	home bias in Mexico	0.71
a	outsourcing share	0.24
m	labor supply elasticity	1
f	risk aversion	2
n	relative size of US	0.74
v	relative wealth of Mexico	1/37
$\overline{G_H}$	US mean government demand	0.1651
$\overline{G_F}$	Mexican mean government demand	0.0301

<u>Technology</u>

$\overline{a_H}$	US steady state unit cost	1
$\overline{a_F}$	Mexican steady state unit cost	13.98
B	fixed cost	0.0084
$\bar{z}$	share of outsourcing	0.20
a	US outsourcing slope parameter	-0.9642
$\bar{b}$	US outsourcing level parameter	0.1928
a_d	relative cost slope parameter	-0.0050
$\overline{b_d}$	relative cost level parameter	-2.0784

<u>Shock processes</u>

$$s_a = \begin{bmatrix} 4.308x10^{-5} & -1.502x10^{-5} \\ -1.502x10^{-5} & 2.8534x10^{-4} \end{bmatrix} \qquad r_a = \begin{bmatrix} 0.6046 & 0.0425 \\ 0.1165 & -0.0051 \end{bmatrix}$$

$$s_G = \begin{bmatrix} 3.355x10^{-3} & 7.080x10^{-4} \\ 7.080x10^{-4} & 1.1165x10^{-2} \end{bmatrix} \qquad r_G = \begin{bmatrix} -0.5593 & 0.0790 \\ -0.3140 & 0.2741 \end{bmatrix}$$

Table 6. Model Simulation
Benchmark Case

	(1) All four shocks	(2) U.S. Demand shock	(3) Mexico Demand shock	(4) U.S. Supply shock	(5) Mexico Supply shock	(6) data
Standard deviations:						
$s(Y^*_{os})$	4.08	2.71	1.87	0.19	2.30	4.91
$s(Y_{os})$	2.29	1.55	0.62	0.48	1.40	2.44
$s(Y^*)$	2.01	1.65	0.31	0.11	1.13	1.94
$s(Y)$	1.77	1.64	0.31	0.36	0.39	1.27
$s(Y^*_{os})/s(Y_{os})$	1.78	1.75	3.04	0.40	1.64	2.03
$s(Y^*)/s(Y)$	1.14	1.01	1.01	0.31	2.94	1.53
$\frac{s(Y^*os)/s(Yos)}{s(Y^*)/s(Y)}$	1.58	1.74	3.00	1.28	0.56	1.33
Correlations						
$corr(Y^*_{OS},Y_{OS})$	0.77	0.98	-0.77	0.90	1.00	0.36
$corr(Y^*,Y)$	0.91	1.00	1.00	0.91	1.00	0.24
$corr(Y^*_{OS},Y^*)$	0.87	0.99	-0.14	0.99	1.00	0.36
$corr(Y_{OS},Y)$	0.85	1.00	0.73	1.00	1.00	0.62

Table 7. Model Simulation
Sensitivity to alternative calibration of A'(z)

	(1)	(2)	(3)	(4)	(5)
$A'(\bar{z})$:	-0.001	-0.1	-1	-2	data
Standard deviations:					
$s\ (Y^*_{os})$	4.08	3.57	3.08	3.02	4.91
$s\ (Y_{os})$	2.29	2.30	2.36	2.38	2.44
$s\ (Y^*)$	2.01	1.94	1.91	1.92	1.94
$s\ (Y)$	1.77	1.78	1.80	1.82	1.27
$s\ (Y^*_{os})/\ s\ (Y_{os})$	1.78	1.56	1.31	1.27	2.03
$s\ (Y^*)/\ s\ (Y)$	1.14	1.10	1.06	1.06	1.53
$\frac{s\ (Y^*os)/s\ (Yos)}{s\ (Y^*)/s\ (Y)}$	1.58	1.42	1.23	1.20	1.33
Correlations					
$corr(Y^*_{OS}, Y_{OS})$	0.77	0.88	0.97	0.97	0.36
$corr(Y^*, Y)$	0.91	0.90	0.87	0.88	0.24
$corr(Y^*_{OS}, Y^*)$	0.87	0.89	0.93	0.94	0.36
$corr(Y_{OS}, Y)$	0.85	0.87	0.89	0.90	0.62

Table 8. Model Simulation
Alternative Versions of the Model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
firm entry:	translog	translog	CES	CES	no entry	no entry	data
endogenous outsourcing:	yes	No	yes	no	yes	no	
Standard deviations:							
$s\,(Y^*_{os})$	4.08	3.01	4.05	2.72	3.84	2.77	4.91
$s\,(Y_{os})$	2.29	2.37	2.04	2.16	1.79	2.06	2.44
$s\,(Y^*)$	2.01	1.89	1.97	1.84	1.92	1.83	1.94
$s\,(Y)$	1.77	1.80	1.71	1.77	1.66	1.74	1.27
$s\,(Y^*_{os})/\,s\,(Y_{os})$	1.78	1.27	1.99	1.26	2.15	1.35	2.03
$s\,(Y^*)/\,s\,(Y)$	1.14	1.05	1.15	1.04	1.16	1.05	1.53
$\frac{s\,(Y^*os)/s\,(Yos)}{s\,(Y^*)/s\,(Y)}$	1.58	1.21	1.73	1.22	1.86	1.29	1.33
Correlations							
$corr(Y^*_{OS},Y_{OS})$	0.77	0.97	0.70	0.97	0.65	0.96	0.36
$corr(Y^*,Y)$	0.91	0.85	0.91	0.84	0.90	0.84	0.24
$corr(Y^*_{OS},Y^*)$	0.87	0.94	0.85	0.93	0.83	0.92	0.36
$corr(Y_{OS},Y)$	0.85	0.89	0.84	0.88	0.80	0.86	0.62

Figure 1: Industry Shares of Maquiladora Employment in Mexico

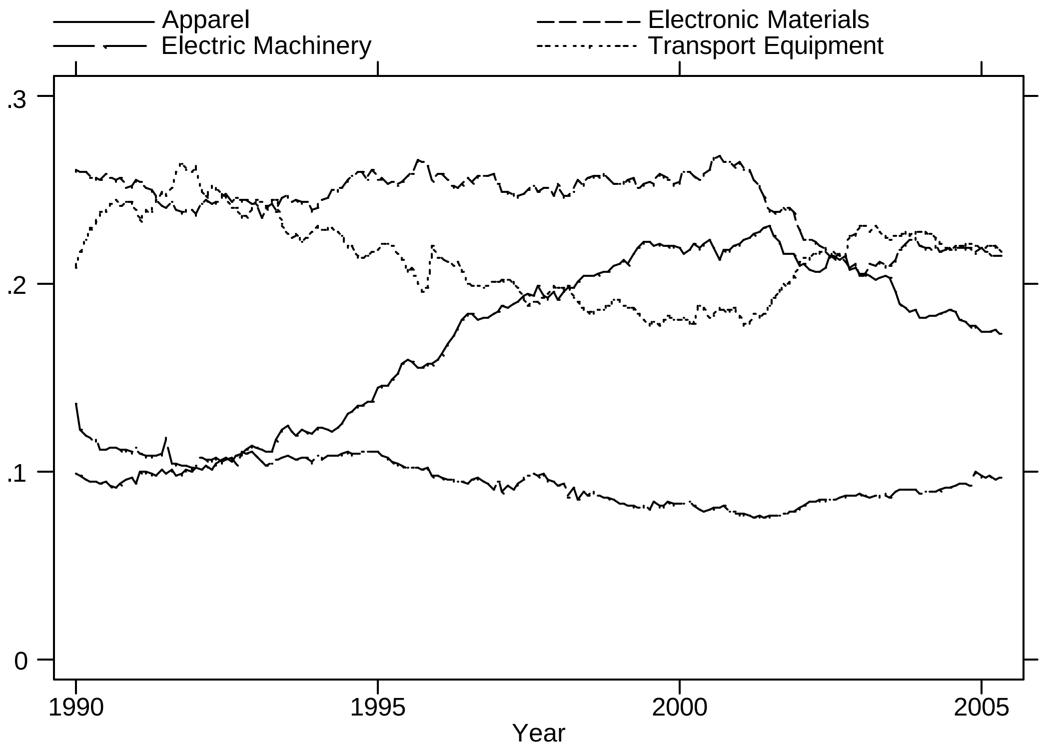

Figure 2: Maquiladora Activity in Mexico
(log values)

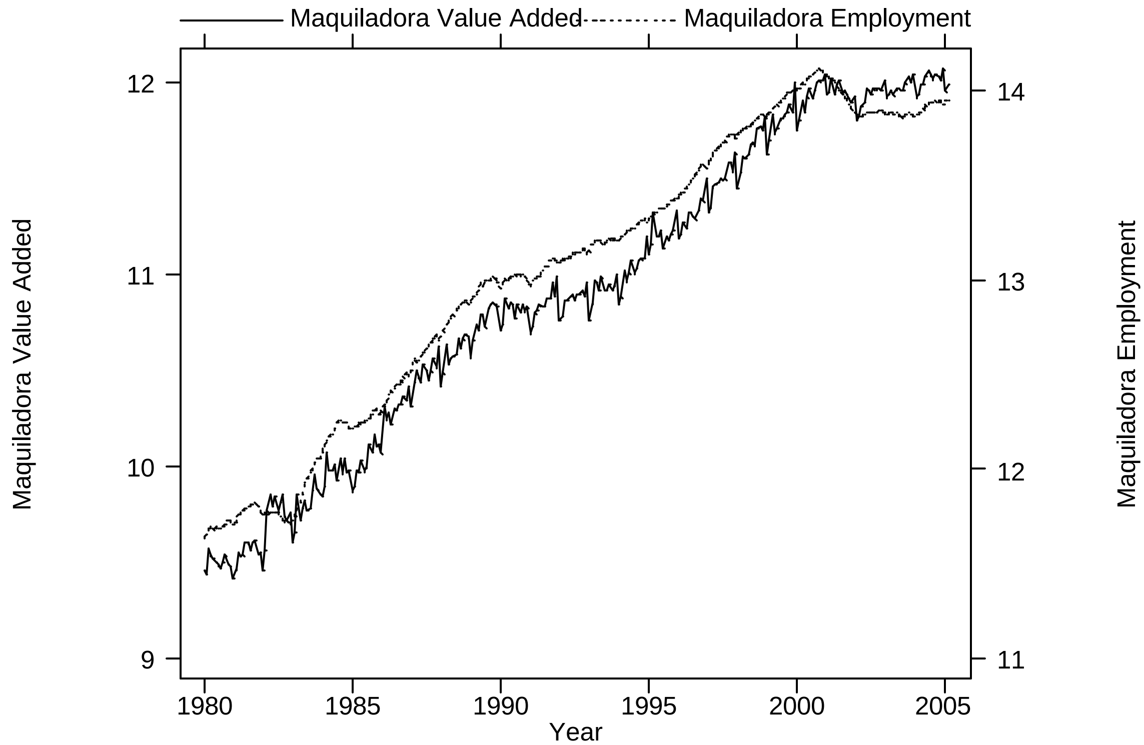

Figure 3: Wage Bill for Production **Workers in Mexico and U.S. Outsourcing Industries**
(log real values, seasonally adjusted and HP filtered)