Exchange Rate Volatility and Exports: The Case of Colombia

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Abstract:

In this chapter, we investigate the impact of exchange rate volatility on the firm's exports. Using plant-level panel data from the Colombian Manufacturing Census, we estimate a dynamic export equation using panel data techniques (the *system-GMM estimator*) developed by Arellano and Bover (1995) and Blundell and Bond (1998). Our estimates imply a small negative impact of exchange rate volatility, constructed either using a GARCH model or a simple standard deviation measure, on the plant's decision to export (the extensive margin) and on the volume of exports as a share of total sales (the intensive margin). We further find that the negative impact of volatility is especially pronounced for plants in the second quartile of the size distribution, which are small and moderate size plants that are most likely to enter foreign markets or increase sales abroad when given a small export incentive. Finally, we show that employing plant-level data vs. industry-level data in the empirical analysis is preferable as it produces more precise and reliable estimates of the volatility effect. We conclude with a discussion of future directions in this line of research.

Key Words: Exchange rate volatility; Exports; Colombia

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Introduction

Researchers and policy makers have been interested in determining the impact of exchange rate volatility on exports ever since the Bretton Woods system broke down in the early 1970s.Since then, for the most part, previously fixed exchange rates among major currencies have been allowed to float. In this setting, economic theory offers little guidance to researchers and policy makers – more volatile exchange rates can have both negative and positive effects on exports (international trade). For example, costly (short-run) adjustment of production factors and (firm owner's) risk aversion may depress firm's exports in the face of higher exchange rate volatility. On the other hand, convexity of the profit function with respect to export prices may lead to a positive impact (see De Grauwe 1988). Hence, evaluating if the overall effect of exchange rate volatility on exports is positive or negative remains an empirical issue.[1]

In the last three decades, researchers have estimated both positive and negative impacts of volatility on exports. Earlier work (e.g., Thursby and Thursby 1987) finds large negative effects of the exchange rate volatility on trade. Later studies find small negative effects (e.g., Frankel and Wei 1993; Eichengreen and Irwin 1995; Frankel 1997, Clark et al. 2004) or positive effects (Klein 1990). Recent empirical work has also underscored the importance of heterogeneity in the impact across industries or countries, which differ in their ability to hedge against volatility (Maskus 1986; Langley et al. 2000, Cho et al. 2002, Clark et al. 2004, Kandilov 2008, Coric and Pugh 2010). In short, perhaps the best way to summarize the empirical findings thus far is to say that they are not conclusive, but they do suggest a weak negative relationship

[1] There is also a related literature on the impact of currency unions on trade (see Frankel and Rose, 2002) as well as research trying to understand the sources of bilateral exchange rate volatility (Klein and Shambaugh, 2008; Devereoux and Lane, 2003).

between exchange rate volatility and exports. As Clark et al. (2004) note, however, this impact is estimated to be economically small and is "…by no means a robust, universal finding." Coric and Pugh (2010) provide a more comprehensive survey of the literature, which largely employs country-level and industry-level (or product-level) data to estimate the impact of volatility on exports. Subsequent to Coric and Pugh (2010), work by Solakoglu et al. (2011) has provided the first (to our knowledge) firm-level evidence on the impact of exchange rate volatility on exports. They use data on large, predominantly manufacturing firms from Turkey and a simple measure of exchange rate volatility based on the standard deviation of the monthly bilateral exchange rate in a given year to show that there is no systematic relationship (neither positive nor negative) between exchange rate volatility and firm-level exports.[2]

In this chapter, we consider the case of Colombia. Using a plant-level panel from the Colombian manufacturing sector, we show that exchange rate volatility has a modest negative impact on the plant's exporting decision – both along the extensive margin (the decision to enter foreign markets) and the intensive margin (the amount of output supplied to foreign countries).[3] An important advantage of using plant-level panel data is that it allows us to control for unobservable plant effects that likely affect exports and volatility simultaneously. We also show that using detailed plant-level data on exports, instead of the more aggregate industry-level data, provides more precise and reliable identification of the exchange rate volatility effect. Based on previous evidence in Roberts and Tybout (1997), and Bernard and Jensen (2004), we estimate a

[2] Their results suggest both positive and negative effects, which are small and mostly statistically insignificant across different econometric specifications.

[3] The data-set on manufacturing plants we use comes from the Colombian Statistical Institute (Departamento Administrativo Nacional de Estadistica, DANE) and it spans the period from 1981 to 1991. Earlier work that uses these Manufacturing Census data includes Roberts and Skoufias (1997), Roberts and Tybout (1997), Das et al. (2007), Kandilov and Leblebicioglu (2011).

dynamic export equation using panel data techniques developed by Arellano and Bover (1995) and Blundell and Bond (1998).[4] We employ a GARCH process to model the exchange rate between the Colombian peso and the currencies of Colombia's trading partners and to construct the conditional exchange rate volatility at the industry level.

Our estimates indicate that volatility has a small negative effect on the plant's likelihood of entering foreign markets and on the plant's exports as a fraction of total sales. The results from our baseline specification imply that a decline of two standard deviations in the conditional volatility leads to a 10-percent increase in the plant-level probability of exporting. Furthermore, we find that a decrease of two standard deviations in the conditional volatility results in an 11-percent increase in exports as a fraction of total sales. Similar results hold if we instead use a more basic measure of exchange rate volatility – the unconditional volatility, which is simply constructed as the standard deviation of the difference in the monthly exchange rate. Additionally, guided by the theoretical work on plant productivity and export market participation pioneered by Melitz (2003), we also investigate the heterogeneity in the impact of volatility across plants of different productivity (size). We find that the negative effect of exchange rate volatility is most pronounced in the second quartile of the size distribution, i.e. for plants of small and moderate size that are most likely to enter foreign markets or increase sales abroad when given a small export incentive. Finally, we demonstrate empirically that using plant-level data instead of industry-level data leads to more precise and reliable estimates of the volatility effect.

[4] Roberts and Tybout (1997) quantify the impact of sunk costs associated with export market entry in Colombia. Bernard and Jensen (2004) use data on U.S. manufacturing plants to model the decision to export.

The rest of this chapter is organized as follows. In the next section we describe the data that we use in order to estimate the impact of exchange rate volatility on exports. In section 3, we provide details on the construction of the exchange rate volatility measures that we employ in our analysis. Section 4 lays out our econometric specification, and the following section presents and discusses the results. The last section concludes and offers directions for future research.

2. Data

To estimate the effect of exchange rate volatility on export behavior, we use the Colombian manufacturing Census annual plant-level panel data from 1981 to 1991.[5] The data, which are described in detail in Roberts and Tybout (1996), include all establishments with at least 10 employees and were originally collected by the Colombian Statistical Institute (Departamento Administrativo Nacional de Estadistica, DANE). The Census data contain information on plant's sales, value added, employment, wages, exports, investment, and other plant characteristics. Each establishment is classified into one of the 28 three-digit ISIC (International Standard Industrial Classification, revision 2) industries.

During the 1980s, the exchange rate policy in Colombia was characterized by a crawling peg with the Colombian peso depreciating in real terms and exports rising (Jaramillo et al. (1999)). While Colombia exports goods from each of the three-digit ISIC industries, there are large differences across industries in the number of trading partners and export destinations.[6,7] Colombia's largest trading partners include the United States, Japan, Germany, and Venezuela. Unfortunately, the Colombian manufacturing Census data from this period do not contain plant-

[5] While an establishment is not necessarily a single-plant firm, most Colombian firms operate only one plant (Das et al. 2007).

[6] Food, textiles, and industrial chemicals are some of the industries with the largest volume of exports.

[7] Leather products are mostly sold to Europe and the United States, while some fabrics are exported mainly to trading partners in South America.

level information on export destinations. To identify trading partners at the industry level, we use industry exports and imports data from the World Bank's Trade and Production Database.[8] We use these data to compute partners' trade shares and use them to construct the industry-level (three-digit ISIC) exchange rate volatility measures, as we describe in the next subsection. Table 1 presents the summary statistics, which indicate that about 15 percent of all plant-year observation feature positive exports. Additionally, exports represent 17.4 percent of total sales for plants that service foreign markets.

Measuring Exchange Rate Volatility

A number of different exchange rate volatility measures have been used in empirical work (see, for example, Frankel and Wei 1993; Rose 2000; Cho et al. 2002; Clark et al. 2004; Tenreyro 2007). However, there is no consensus on which measure is the most appropriate, which in part depends on the particular empirical set-up (see Clark et al. 2004). For example, the type of volatility measure employed depends on the aggregation level of the trade flows (bilateral vs. multilateral) and the time horizon (short-run vs. long-run). Often, researchers construct a volatility measure by using the standard deviation of the difference in the annual or monthly exchange rate (see, for example, Frankel and Wei 1993; Rose 2000; Tenreyro 2007). Such measures reflect the unconditional, realized volatility. To capture the ex ante exchange rate uncertainty, we follow Kandilov and Leblebicioglu (2011) and use a GARCH specification (Bollerslev 1986; Engle 1982) to model the conditional exchange rate variance.

Employing a GARCH process allows the variance of the exchange rate changes to be time dependent and it further accounts well for the heavy tails of their distribution. Since it was first introduced, the GARCH model has been used by a growing number of researchers to

[8] These data are available on-line at *http://www.worldbank.org*.

construct a measure of exchange rate volatility – see, for example, Baillie and Bollerslev (1989), Pozo (1992), Arize et al. (2000), Clark et al. (2004), May (2007), and Wang and Barrett (2007), Kandilov (2008), and Kandilov and Leblebicioglu (2011).

To maintain flexibility, we estimate a separate GARCH model for each year of our sample from 1981 to 1991. Colombia has a large number of trading partners, which makes it computationally burdensome to estimate a separate GARCH (1, 1) specification for the exchange rate process of each partner. Hence, we follow the practical solution of Clark et al. (2004) and we group Colombia's trading partners into two categories – developed and developing. We then estimate the GARCH (1,1) process for the exchange rates separately for each of the two categories of countries for every year from 1981 to 1991 using monthly data on exchange rates from the preceding five years. The exchange rate volatility measure we construct therefore captures medium to long run volatility. Specifically, for a given year t, t = 1981, 1982, . . . , 1991, we estimate two versions of the following GARCH (1,1) specification (one for each of the two categories of trading partners):

(1) $$100\Delta X_{kzm} = \psi_0 + \xi_{kzm}$$

(2) $$\xi_{kzm} \mid \mathrm{I}_{zm-1} \sim \mathrm{N}(0, h_{zm})$$

(3) $$h_{zm} = \delta_0 + \delta_1 \xi^2_{kzm-1} + \delta_2 h_{zm-1},$$

where X_{kzm} is the natural logarithm of the real bilateral exchange rate between country k's currency and the Colombian Peso in month m = 1, 2, …, 12, of year $z = t - 1, \ldots, t - 5$.[9] We estimate 22 (= 11 years * 2 categories of trading partners) different GARCH (1,1) models and

[9] The estimated coefficients in the GARCH (1,1) regressions ensure that all time-varying variance processes are stable.

use the last estimated conditional standard deviation of each country pair (divided by 100) as the approximation of the conditional exchange rate volatility, V_{kt}^{C} , at the beginning of the next period (see Clark et al. (2004)). The conditional volatility for 1991, for example, is the estimated conditional standard deviation for December 1990 in the GARCH (1,1) model using data from January 1986 to December 1990.

Previously, research in this area has used both the nominal exchange rate (e.g., Tenreyro (2007) and the real exchange rate (Arize et al. (2000), Cho et al. (2002), and Kandilov (2008), and Kandilov and Leblebicioglu (2011)) in the construction of an exchange rate volatility measure. Here, we choose the real rate to construct our preferred measure of volatility, V_{kt}^{C} because, theoretically, profits are affected by both the nominal exchange rate and prices of traded goods (see Maskus (1986)). For a large number of industrialized and some developing countries the choice between the real and the nominal rate in the construction of an exchange rate volatility measure would be of little consequence because prices tend to change slowly. The choice would matter in high inflation (hyper-inflation) settings such as, for example, in Brazil and Argentina in the 1980s, when nominal exchange rate volatility was higher than the real rate volatility.[10] To construct real bilateral exchange rates, we use data on nominal bilateral exchange rates and trading partners' CPI indices from the IMF *International Financial Statistics* series. Increase in the real exchange rate implies a depreciation of the Colombian peso.

To check for robustness, we also construct and use another measure of exchange rate volatility that is based on the standard deviation of the difference in the monthly real exchange rate (see, for example, Clark et al. 2004 and Tenreyro 2007). As we previously discussed, this

[10] Early empirical work by Thursby and Thursby (1987) has found that real and nominal exchange rate volatilities do not affect trade flows differently.

measure reflects the unconditional, realized volatility. Formally, for a given year *t*, *t* = 1981, 1982, …, 1991:

$$(4)\qquad V_{kt}^{U} = St.Dev.[X_{kz,m} - X_{kz,m-1}], \quad m = 1, 2, ..., 12; \quad k = t-5, ..., t-1.$$

Once the bilateral conditional (V_{kt}^{C}) and unconditional (V_{kt}^{U}) exchange rate volatility measures are computed, we use them to construct industry-specific exchange rate volatility measures at the three-digit ISIC (revision 2) level. Let XV_{jt}^{GARCH} denote the industry-level exchange rate volatility in industry *j* and year *t*. Then,

$$(5)\qquad XV_{jt}^{GARCH} = \sum_{k} TradeShare_{jk} * V_{kt}^{C},$$

where

$$(6)\qquad TradeShare_{jk} = \frac{1}{T}\sum_{t}\frac{M_{jkt} + E_{jkt}}{\sum_{k} M_{jkt} + E_{jkt}},$$

and V_{kt}^{C} is the conditional exchange rate volatility in year *t* between country *k*'s currency and the Colombian peso, *T* denotes the length of the sample period (11 years), M_{jkt} denotes imports from trading partner *k* into Colombia, E_{jkt} denotes exports from Colombia to a trading partner *k* in industry *j* and year *t*. The weights in equation (5), i.e. the partner trade shares, are fixed over time (averaged within an industry across the sample period), so that the variation over time in the industry-specific exchange rate, XV_{jt}^{GARCH}, only comes from changes in the conditional exchange rate volatility and not from (potentially endogenous) fluctuations in partner's trade shares. To construct the industry exchange rates we use Colombia's 29 largest trading partners, each of which accounts for at least 5 percent of bilateral trade in at least one (three-digit ISIC) industry. These 29 trading partners collectively account for nearly 80 percent of Colombia's total trade. Finally, using the second measure of (unconditional) volatility, V_{kt}^{U}, in place of V_{kt}^{C} in equation (5), we construct the alternative industry-level exchange rate volatility measure XV_{jt}^{StDev}.

Table 2 presents the average (over the sample period) conditional and unconditional industry exchange rate volatility measures for all 28 three-digit ISIC industries. The two measures are highly positively correlated, as expected, with similar means and standard deviations. Table 2 suggests that there is substantial heterogeneity in volatility across industries. For example, the average conditional exchange rate volatility in Electrical Machinery is 0.089, while at 0.312, it is more than 3 times higher in Non-ferrous Metals. Additionally, note that in general, exchange rate volatility has increased over the sample period from 1981 to 1991 – the change in volatility is positive in almost all industries. Here, we also find significant heterogeneity across industries – with Non-ferrous Metals and Food, for example, experiencing a significant jump in volatility from the beginning of the sample in 1981 until the end in 1991, while Leather Products and Electrical Machinery undergoing almost no change in volatility over the sample period.

4. Empirical Methodology

As exchange rate volatility affects the firm's profitability, it can affect firm's export behavior along two dimensions. First, it can affect the firm's decision to enter the export market (the extensive margin), and second, it can affect the amount of output the firm supplies to foreign consumers (the intensive margin). We start off by analyzing the impact of exchange rate volatility on the firm's propensity to export. Let the binary variable EXP_{ijt}^{DUM} take on a value of one when firm *i* in industry *j* exports in a given year, *t*, and zero otherwise. Following Bernard and Jensen (2004), we adopt a linear probability framework to estimate the effects of exchange rate volatility on the propensity to export, controlling for unobservable plant-specific characteristics. Subsequently, we assess the impact of exchange rate volatility on the firm's exports by estimating a second model whose dependent variable is exports as a fraction of total sales, EXP_{ijt}^{FRAC} ($0 \leq EXP_{ijt}^{FRAC} \leq 1$). Specifically, we adopt the following empirical specification for both the extensive and the intensive margin of exports as a dependent variable:

$$(7)\ \ \Psi_{ijt} = \alpha_1 \Psi_{ijt-1} + \alpha_1 \Psi_{ijt-2} + \beta' Z_{ijt-1} + \rho_1 XV_{jt-1} + \rho_2 \Delta X_{jt-1} + \rho_3 S_{jrt-1} + \mu_i + \tau_t + \varepsilon_{ijt},$$

where Ψ_{ijt} is either the export dummy variable (EXP_{ijt}^{DUM}) or exports as a fraction of total sales (EXP_{ijt}^{FRAC}) for plant *i* in industry *j* in year *t*. The vector Z_{ijt-1} collects all relevant plant-level characteristics, such as the capital to labor ratio and the (natural logarithm of) total employment; XV_{jt-1} denotes the exchange rate volatility measure for industry *j* in year *t-1*; ΔX_{jt-1} denotes the annual difference in the natural logarithm of the real exchange rate for that industry; and S_{jrt-1} captures the spillovers from export activity within the same industry *j* and region *r* as those of firm *i*'s. The indicator S_{jrt} takes on the value of one if there is a firm other than firm *i* in industry *j* and region *r* that exports in year *t*, and zero otherwise.

Equation (7) includes two lags of the dependent variable in addition to the vector of plant-level characteristics that can affect the decision to export. The lags of the dependent variable are included to accommodate for the existence of sunk costs to entry into the export market (see e.g., Roberts and Tybout (1997) and Bernard and Jensen (2004)). We consider three additional plant-level characteristics which tend to be positively correlated with the plant's unobserved time-varying productivity and therefore can affect the decision to export. First, we include the (natural) logarithm of total employment, which captures plant's size. Further, we include the capital-labor ratio and a measure of labor quality, defined as the ratio of white collar workers to total employment. As capital and skill intensity are associated with higher productivity, they would both make it more likely for the firm to enter the export market. In order to minimize endogeneity and simultaneity concerns in the empirical specification, we lag these three explanatory variables by one period.

Equation (7) also includes plant-specific fixed effects, μ_i, that capture the unobserved, time-invariant, plant-level determinants of exports, as well as year effects, τ_t, that capture aggregate, economy-wide fluctuations. Macroeconomic factors common to all firms, such as changes in the interest rate, will be absorbed in these year effects. However, firms in different industries might face different economic conditions and there might be industry-specific innovations affecting productivity within that particular industry. In order to allow for heterogeneous productivity growth, in some specifications, we additionally include interaction terms between a time trend and a full set of eight aggregate (two-digit) industry dummies. Moreover, in some specifications, we also include interaction terms between the trend and a full set of nine region dummies in order to control for region-specific productivity changes and economic conditions.[11]

[11] The regions, defined by major metropolitan areas, are as follows: Bogota, Soacha; Cali, Yumbo; Medellin, Valle de Aburra; Manizalles, Villamaria; Barranquilla, Soledad; Bucaramanga, Giron, Floridablanca; Pereira, Santa Rosa de Cabal, Dosquebradas; Cartegena; and rest of the country.

We estimate the dynamic export equation (7) using the *system-GMM estimator* of Arellano and Bover (1995) and Blundell and Bond (1998). This estimator for panel data sets with short time dimension addresses the potential biases that arise from the correlation between the plant fixed effects, μ_i, and the lagged dependent variable, Ψ_{ijt-1}, as well as the endogeneity of plant characteristics (total employment, capital-labor ratio and labor quality) included in vector Z_{ijt-1}. The *system-GMM estimator* combines the first-difference equations, whose regressors are instrumented by their lagged levels, with equations in levels, whose regressors are instrumented by their first-differences.[12] We treat all of the plant specific variables as endogenous, and use lagged values dated *t-2* and *t-3* as the GMM-type instruments. Due to the persistence in exports, lagged values dated *t-3* of exports (both EXP_{ijt}^{DUM} and EXP_{ijt}^{FRAC}) were shown to be invalid instruments using the Sargan-Hansen tests of overidentification. For the lag dependent variables, only the lagged values dated *t-4* are used as instruments. The full set of instruments can be found at the end of each table. We employ and report the Sargan-Hansen tests of over-identification to test for the validity of our instruments.[13]

5. Results

The results from our first baseline specification (7), which estimates the impact of exchange rate volatility on the plant-level decision to export in Colombia, are reported in Table 3. In this first set of results on the extensive margin in subsection 5.1, we evaluate the effect of

[12] The *system-GMM estimator* builds on the *difference-GMM estimator* of Arellano and Bond (1991), which uses only the differenced equations, instrumented by the lagged levels of the regressors. If the regressors are persistent, then their lagged levels are shown to be weak instruments. See Arellano and Bover (1995) and Blundell and Bond (1998) for more details. To avoid this drawback of the *difference-GMM estimator*, we opt for the *system-GMM estimator*.

[13] All the estimations and tests were done using the *xtabond2* command in Stata 11.

exchange rate volatility using both measures of volatility – one derived from the GARCH model of the Colombian exchange rate (XV_{jt}^{GARCH}) and the second measure based on the standard deviation of the difference in the monthly exchange rates (XV_{jt}^{StDev}). In subsection 5.2, we consider the intensive margin and present the results we obtain from estimating equation (7) using plant-level exports as a fraction of total sales as the dependent variable. In the following subsection 5.3, we also show that using industry-level, instead of plant-level, data on exports to identify the effect of exchange rate volatility produces ambiguous results – the estimated impacts with the aggregate industry-level data on exports are much smaller in magnitude, statistically insignificant with both positive and negative signs depending on the measure of volatility employed. Finally, in subsection 5.4, we discuss the heterogeneity in the impact of the exchange rate volatility on the decision to export and the level of exports (as a fraction of sales), across firms of different size (productivity).

5.1 The Extensive Margin

Column (1) of Table 3 presents the results from our baseline specification (7), which includes both firm and year fixed effects, using the GARCH measure of exchange rate volatility, XV_{jt-1}^{GARCH} . The estimates reveal that volatility has a negative and statistically significant impact on the plant's decision to export. The estimated coefficient of -0.095 (standard error = 0.038) implies that a two-standard-deviation reduction in the conditional volatility (one standard deviation of XV_{jt-1}^{GARCH} is 0.081, see Table 1) leads to a 1.54 percentage points increase in the probability of exporting. The magnitude of the effect implies that at the mean propensity to export (0.148, see Table 1), this reduction in the conditional volatility increases the probability of exporting by about 10 percent.[14] While this is the first (to our knowledge) estimate of the effect of exchange rate volatility on plant's propensity to export, these results are broadly consistent with previous research which mostly finds weak negative effects of exchange rate volatility on the level of exports.

To check for robustness, we further include region-specific time trends (capturing, for example, dynamic productivity differences across regions in Colombia), as well as aggregate two-digit industry-specific trends (capturing industry-specific productivity or costs trends).[15] The specification with region-specific trends is presented in column (2) of Table 3, and the results show that the estimate of the conditional exchange rate volatility remains unchanged. Once we additionally include two-digit industry-specific trends (column 3, Table 3), the coefficient on the exchange rate volatility maintains its negative sign but declines by half, losing statistical significance at the 5 percent level. This is not surprising as the exchange rate volatility is computed at the three-digit industry level and including two-digit industry-specific time trends absorbs a lot of the variation in volatility. The impact is then only identified using annual variation from the two-digit industry time trend. This estimate implies that a two-standard-deviation reduction in the conditional volatility would lead to only about a 5-percent increase in the propensity to export.

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[14] Although small at face-value, the impact of reducing the exchange rate volatility on the probability of exporting is non-trivial when compared to the estimated effects of changing some of the plant-level characteristics. For example, to generate a similar 10 percent increase in the probability of exporting, employment would have to increase by 78 percent given the estimated coefficient on log of employment (0.019) and the mean propensity to export of 0.148.

[15] We use eight aggregate industries (equivalent to two-digit ISIC manufacturing industry aggregates) and nine regions corresponding to the major metropolitan areas in Colombia (see footnote 11).

Columns (4) - (6) of Table 3 report the results from our baseline specification (7) with the standard deviation measure of exchange rate volatility, XV_{jt-1}^{StDev}. Consistent with our findings using the GARCH measure, the coefficient on the volatility measure (XV_{jt-1}^{StDev}) in column (4) is negative and statistically significant at -0.197 (0.066). The estimate implies that a two-standard deviation reduction in XV_{jt-1}^{StDev} (0.110 = 2* 0.055) leads to a 2.17 percentage points (14.64 percent at the mean) increase in the probability of exporting. Similar to the results with the GARCH measure, the coefficient on in XV_{jt-1}^{StDev} declines substantially and is no longer statistically significant when the two-digit industry-specific time trends are included along with the region-specific trends.

In all six columns, the first lag of the export dummy, which is included to capture the sunk cost of entering export markets, is positive and highly significant. Focusing on the results in the first column, the coefficient on lagged export status implies that having exported in the previous year increases the probability of exporting in the current year by about 73 percent. This estimate is almost twice as large as the coefficient Bernard and Jensen (2004) obtain from a similar Arellano-Bond GMM specification using data for U.S. manufacturing plants. This suggests that the role of entry costs into export markets may be even bigger for firms in developing countries, such as Colombia. The second lag of the export dummy also enters positively and it is statistically significant at the 10 percent level in either of the two specifications with two-digit industry and region trends – using both measures of volatility – which indicates that entry costs are quite persistent.

The other firm-specific determinants of the propensity to export – the logarithm of employment, the capital-labor ratio, and the measure of labor quality (the ratio of white collar workers to the total number of workers) – are all positive, as expected, and the first two are statistically significant, suggesting that larger and more capital-intensive plants are more likely to export. Finally, the results also show that export activity in the firm's industry and geographic region raises the firm's own propensity to export – the coefficient on spillovers (S_{jrt-1}) is estimated to be positive and it is significant at the 10 percent level in the baseline specifications in columns (1) and (4). This is in line with expectations, but it differs from the findings in Bernard and Jensen (2004), who find negative but mostly insignificant spillover effects for U.S. manufacturing plants.

All specifications in Table 3 are supported by the tests of over-identifying restrictions, for which the Hansen test statistic fails to reject the validity of the instrument sets (the *p*-values ranging from 0.163 to 0.196). Moreover, the tests for serial correlation, which are applied to the residuals in the first differenced equations, show that we can reject the null-hypothesis of no first-order serial correlation, but cannot reject the null-hypothesis of no second order serial correlation.[16] The fact that the errors only have first order autocorrelation confirms the validity of instruments dated *t-2* and *t-3*.

5.2 The Intensive Margin

Table 4 presents the results from estimating equation (7) using plant exports as a fraction of sales as the dependent variable. With the exception of the two lags of the dependent variable, we keep the set of right-hand side variables same as in the previous section where we estimated the impact of exchange rate volatility on the propensity to export. In this specification, we use two lags of exports as fraction of sales to accommodate the persistence in the export intensity

[16] Assuming that the residuals, ε_{ijt} , in equation (1) are *i.i.d*, we expect $\Delta\varepsilon_{ijt}$ in the first-differenced equations to have first-order autocorrelation.

that can arise as a result of the sunk cost of entering the export markets. Again, as before, we consider both the GARCH and the standard deviation measures of volatility. Column (1) of Table 4 shows the results from the baseline specification using the GARCH measure of volatility. Consistent with the results from the model using the propensity to export as a dependent variable, here, we also find that exchange rate volatility has a negative and statistically significant effect on the volume of exports. At -0.020 (standard error = 0.007), the coefficient on XV_{jt-1}^{GARCH} in column (1) implies that at the mean, the magnitude of the elasticity of exports (as a fraction of total sales) is 0.12. Alternatively, a two-standard-deviation reduction in the conditional volatility leads to a 0.32 percentage points increase in the share of exports, which is equivalent to an 11.17 percent increase at the mean value of exports (as a fraction of total sales) in our sample. Given the coefficient of -0.066 on XV_{jt-1}^{StDev} in column (4), the elasticity of exports with respect to the unconditional exchange rate volatility is higher at 0.32. Once we include both region- and two-digit industry-specific time trends in the specification using the unconditional volatility measure (XV_{jt-1}^{StDev}), the coefficient declines to -0.025 and implies an elasticity of 0.12.

The signs of coefficients on the other determinants of exports in column (1) of Table 4 are similar to the ones in column (1) of the Table 3, where we considered the propensity to export as a dependent variable. In terms of the plant-specific characteristics, the coefficient on lagged exports implies a significant degree of persistence, and the size of the plant (measured by the logarithm of total employment) is positive and statistically significant. While the capital-labor ratio and labor quality (the fraction of white collar workers in total employment) have positive effects in this specification, only labor quality is statistically significant at the 5 percent level.

5.3 Estimating the Impact of Exchange Rate Volatility on Exports Using Industry-level Data

In order to highlight the importance of using disaggregated data in identifying the effects of exchange rate volatility on exports, we next aggregate the plant-level information to a 3-digit ISIC level (see Table 2 for the list of industries) and estimate equation (7) using industry-level data on exports (as a fraction of total sales). The results are presented in Table 5. The coefficient on exchange rate volatility (XV_{jt-1}) is much smaller in magnitude than the estimate in Table 4, where we employed the plant-level exports data, and it is very imprecisely estimated with both the GARCH and the standard deviation measures. While the former measure has a negative impact on exports, the latter is actually estimated to have a positive effect at the industry level. Moreover, except for the lagged value of exports, none of the other determinants of exports is significant in Table 5. Whereas the estimates in Tables 3 and 4 clearly show that exchange rate volatility has a small negative effect on exports, the industry-level results in Table 5 are ambiguous. Hence, the small, inconsistent, and imprecise estimates obtained with the aggregate industry data underscore the importance of utilizing firm-specific (or plant-specific) variation in export dynamics. Further, using industry-level data one cannot evaluate the differences in the effect of volatility across plants of different size (productivity).

5.4 Heterogeneity in the Impact of Exchange Rate Volatility

Before we conclude, we present the estimates in Table 6, which shed light on the heterogeneity of the impact of exchange rate volatility on the probability of exporting as well as the volume of exports across establishments of different size. Because the firms' decision on export market entry and the volume of exports varies with productivity, which tends to be positively correlated with size, in the next specification, we allow the effect of exchange rate volatility to differ across the four quartiles of plants' (initial) size distribution. Large and productive firms might not be affected by marginal changes in the exchange rate volatility, since they would most likely be already operating in the export market, and would be able to absorb the fluctuations in the exchange rate in their profit margins. Moreover, larger firms would find it easier to protect themselves from fluctuations in the real exchange rate as they would be more likely to have access to credit markets. Similarly, we would expect to find a smaller impact on the firms at the bottom of the size distribution, as they might be too small to enter the export market regardless of exchange rate volatility. In contrast, volatility can have a large effect on exports, along both the extensive and the intensive margins, for firms that are in the middle of the size distribution. Such firms are likely to be on the margin and a reduction in exchange rate volatility may increase their likelihood of export market entry. Similarly, a reduction in volatility can improve the profitability of exporting, and increase the fraction of output that existing exporters supply to the foreign market.

To empirically test for heterogeneity in the impact of exchange rate volatility on firm-level exports in the Colombian manufacturing sector, we divide all firms into 4 groups - the four quartiles of the initial plant size distribution, where initial size is a proxy for productivity. We use initial plant-level (natural logarithm of) employment relative to the 4-digit-industry average as a measure of the firm's initial size (see Bustos (2011) as well as Kandilov and Leblebicioglu (2012)). We then interact the exchange rate volatility measure with the initial size indicator for the four quartiles, and estimate this expanded version of our baseline model (7).

Columns 1 and 2 in Table 6 present the results for the extensive margin of exports using the GARCH measure of exchange rate volatility.[17] In general, the estimates are consistent with expectations and imply that exchange rate volatility does not affect the probability of entering the export market for the large firms in the top quartile, but it does significantly lower the probability for smaller firms, with the largest impact estimated for firms in the second quartile of the (initial) size distribution. The point estimate of -0.128 (standard error = 0.046) for the second quartile in column (1) is about 35 percent bigger than the average impact of -0.095 (0.038) that we obtained in our baseline specification (see column (1) of Table 3). We find the same pattern for the intensive margin. While a reduction in exchange rate volatility leads firms in the bottom three quartiles, especially the second quartile, to increase their exports (as a fraction of total sales), it leaves exports of the firms at the top quartile of the size distribution mostly unaffected. For plants in the second quartile, the estimate of -0.023 (0.008) yields an impact that is 15 percent higher than the average effect estimated in column (1) of Table 4.

6. Conclusion

Researchers and policy makers have been interested in estimating the impacts of volatility in the exchange rate on exports since the early 1970s when previously fixed exchange rates among major currencies were allowed to float. Theoretically, the effect can be either positive or negative. Empirical work so far has considered different econometric techniques (panel, cross-section, time-series), country coverage (analyzing a single exporter vs. multiple countries), and data at different levels of (dis)aggregation (country-level vs. industry-level vs.

[17] The specifications in Table 6 include the full set of control variables presented in Tables 3 and 4. We omit the presentation of the other estimates for brevity. They are similar in magnitude and significance to the ones presented in Tables 3 and 4. Also, the results using the standard deviation measure are quite similar to the ones presented in Table 6.

firm-level) to show that there is likely a weak negative effect of higher exchange rate volatility on exports. The estimated impact, however, is not robust (for example Klein (1990) uncovered a positive effect), and it is not homogenous across countries and industries (see, for example Cho et al. (2002), Clark et al. (2004), Coric and Pugh (2010), and Solakoglu et al. (2011)).

In this chapter, we employ plant-level data from the Colombian manufacturing sector from 1981 to 1991 to show that exchange rate volatility has a small negative impact on the plant's export dynamics, both along the extensive margin (the decision to enter foreign markets) and the intensive margin (the volume of exports as a fraction of sales). Using plant-level as opposed to industry-level data, which is the type of data almost all of the previous studies have employed (e.g. Clark et al. 2004) is an important advantage for at least three reasons. First, we are able to control for unobservable time-invariant plant characteristics that likely affect exports and volatility simultaneously. Second, we are able to identify the impact of volatility on the extensive margin – the likelihood of export market entry by an individual firm – in addition to the intensive margin – the volume of exports (as a share of total sales). Finally, with detailed plant-level data, we can also estimate the differences in the effect of volatility on plants of different size (productivity). Based on recent theoretical work in Melitz (2003), who incorporates export market entry costs in a heterogeneous firm model, one would expect that an export incentive, such as lower exchange rate volatility, may affect plants differently based on their productivity level. To test this explicitly, we use plant's size (relative to the 4-digit-industry average) as a measure of the plant's productivity and show that the negative effect of exchange rate volatility is most pronounced in the second quartile of the size distribution, i.e., for plants of small and moderate size that are most likely to enter foreign markets or increase sales abroad when given a small export incentive.

Our econometric model is guided by both the theoretical work on firm heterogeneity and exports pioneered by Melitz (2003) as well as previous empirical work by Roberts and Tybout (1997), who quantify the impact of sunk costs associated with export market entry in Colombia, and Bernard and Jensen (2004), who model the decision to export for U.S. manufacturing plants. To this end, we estimate a dynamic export equation using panel data techniques (the *system-GMM estimator*) developed by Arellano and Bover (1995) and Blundell and Bond (1998). To properly compute conditional exchange rate volatility, i.e. to capture the ex-ante exchange rate uncertainty, we use a GARCH process to model the exchange rate between the Colombian peso and the currencies of Colombia's trading partners. The estimates from our baseline specification indicate that a decrease of two standard deviations in the industry's conditional volatility leads to a 10-percent increase in the plant-level probability of exporting. We also find that a decline of two standard deviations in the conditional volatility results in about 11-percent increase in plant's exports as a fraction of total sales. Similar results hold if we instead use a simpler measure of exchange rate volatility – the unconditional volatility, which is constructed as the standard deviation of the difference in the monthly exchange rate. Finally, by aggregating the plant-level export data by industry and repeating the empirical analysis at this more aggregate level, we explicitly show that using detailed plant-level instead of the more aggregate industry-level data on exports provides more precise and reliable identification of the exchange rate volatility effect.

Our findings carry some implications for economic development. If exports help boost firm or industry productivity (via spillovers) and enhance economic growth, as a result of learning-by-exporting or technology/quality upgrading (see, for example, De Loecker, 2013; Alvarez and Lopez, 2008, Verhoogen, 2008, Van Biesebroeck, 2006; Aw, Chung, and Roberts,

2000) among other mechanisms, then real exchange rate volatility may also adversely affect productivity and growth through its negative impact on exports.[18] In today's world, the effects of exchange rate fluctuations are relatively more important than in the past when trade barriers were higher. Hence, governments may be able to mitigate the negative impact of volatility on export performance, productivity, and growth by, for example, providing relevant and timely information about foreign market conditions, producing reliable price data, and facilitating access to finance among other types of policies.

The survey of the existing literature on the impact of exchange rate volatility on exports and the evidence we uncover using the plant-level panel from the Colombian manufacturing sector point to a number of directions for future research on this topic. First, our analysis suggests that using micro-level data is important for a number of reasons that we have already outlined above. Better plant-level data are becoming increasingly more available. We suspect that in the near future, establishment-level data that contain additional details on products and export destinations for each plant will make the identification of the impact of exchange rate volatility on export behavior even more precise, giving researchers and policy-makers a more complete picture of the different plant-level export margins that are affected by exchange rate volatility.

Another fruitful direction for future research on this topic is perhaps a comparative analysis of the impacts of exchange rate volatility on exports dynamics across countries at different stages of financial development, which introduces variation in firms' access to

[18] It is worth noting that the magnitude of the negative effect of real exchange rate volatility on exports may be smaller (than it is in Colombia) in countries where the financial sector is well-developed. Easier access to local finance may enable even small firms to better hedge against real exchange rate volatility.

financing and hedging opportunities.[19] Better access to hedging exchange rate risk will presumably dampen its negative effect on exports. While there certainly exists variation in access to hedging risk across firms, industries, and regions within a country, such variation is likely smaller and more difficult to quantify than the variation that exists across countries at different stages of financial development. Additionally, the variation in exchange rate uncertainty across such countries is likely much higher and it will enable researchers to identify its effects on exports more precisely, including documenting any potential non-linearities in the impact.

[19] For example, one can consider currency invoicing as a hedging opportunity. Using cross-country establishment-level data, one can (better) understand the impact of currency invoicing in mediating the relationship between exchange rate volatility and exports. For recent theoretical work on this topic see Bacchetta and van Wincoop (2005) as well as Goldberg and Tille (2008).

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