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great by
deeds, not by
birth"

-Chanakya

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**Exchange rate volatility and trade responsiveness of
international firms**

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IIMK WORKING PAPER

Exchange rate volatility and trade responsiveness of international firms

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Abstract

This paper analyses, for the first time, trade responsiveness of the international firms (under no-hedging possibilities) linked to both domestic and foreign markets simultaneously, with respect to the random fluctuations in foreign (spot) exchange rates. Uncertainties in the spot exchange rates impart production decisions of the firm. In sum, the firm's elasticity of risk aversion with respect to the standard deviation (or the mean) of the firm's end-period random profit determines the direction of the impact of exchange rate volatility on trade. The analytical model is quantitatively extended, using data from Indian service sector (non-financial) firms over 2004-2015, to empirically estimate the risk-aversion elasticities owing to the exchange rate shocks, for the first time.

JEL classification: D21; D81; F10; F31.

Keywords: Two-moment model; exports; imported intermediate inputs; exchange rate volatility; revenue risk; elasticities of risk aversion.

1. Introduction

One of the most contentious issues in international economics is the effect of the uncertainties associated with the exchange rate fluctuations on the international firms, and therefore, on the entry and exit into export market (extensive margin) as well as on the volume of international trade (intensive margin). There is relatively little evidence on the responses of exports, due to the exchange rate volatilities, at the level of firms or individual producers. Exceptions include Cheung and Sengupta (2013); Berman et al. (2012); Fitzgerald and Haller (2012); Arize et al. (2008); Greenaway et al. (2007); Cheung (2005); Bernard and Jensen (2004a; b); Bugamelli and Infante (2003); and Forbes (2002). However, most of these empirical studies fail to explain how and why should the higher volatilities in foreign exchange rate lead to a reduction in international trade.

Among these, Cheung and Sengupta (2013) examined the impact of exchange rate changes on the volume of exports of the Indian manufacturing firms, i.e. at the intensive margin. They have found negative and significant effects on firms' export shares of exchange rate appreciation. However, Cheung and Sengupta (2013) have also noted, for their sample of Indian firms from 2000 to 2010, that the exchange rate fluctuations have differential firm-specific effects on the export shares, with an asymmetric response towards the exchange rate movement.

There are, unfortunately, paucity of the theoretical contributions linking exchange rate risk and trade using portfolio theory, *without any hedging possibilities*. Among these, most notable have been Broll and Eckwert (1999) and Broll et al. (2006) in this context. The main message from both of these papers was that the impact on the export shares of an international firm owing to an increased exchange rate volatility should be contingent upon the degree of relative risk aversion of the firm.

However, in all of these theoretical contributions, the exporting firm under consideration *cannot simultaneously serve* both domestic and foreign markets. Given this, we have applied the mean-standard deviation approach following Broll and Mukherjee (2016) in order to examine an international firm that serves simultaneously both domestic and export (foreign) markets. Risk preferences only contribute to alter the allocation of production between these two activities, keeping the total production unchanged. Therefore, we do not impose any specific *a priori*

assumption about the firm, for the sake of simplicity and ease of interpretation. This is one of the major contributions of our modelling approach – provides more precise answer with the help of mean-variance modelling approach. Therefore, this paper examine the optimal production and export decisions of a risk-averse firm facing exchange rate uncertainty under mean-variance preferences.¹

Section 2 is devoted to the quantitative analysis using data from Indian service sector (non-financial) firms over 2004-2015. Since estimation of risk aversion elasticities are always important aspects, our paper proposes an example of flexible utility function with nonlinear mean –standard deviation framework that nests all possible risk preference structure; and then using that proposed utility function, we derive a unique structural estimation equation for the empirical analysis to exemplify our theoretical predictions/propositions.

We aim at systematic analyses of economic response in the mean-variance framework. All comparative static effects are described by the marginal rate of substitution between risk and return, i.e. the willingness to pay for a reduction in risk.

1. Theoretical Model

Consider a firm that serves both the domestic market and a foreign country market under exchange rate uncertainty. To start with, let us assume at the beginning of the period the firm produces a single homogeneous good in the home country according to a known cost function the firm produces a single good, according to a cost function, $C(q)$, with $C'(q) > 0$, and $C''(q) > 0$, i.e. marginal costs are increasing (i.e. the firm's production technology exhibits decreasing returns to scale). We suppress the riskless interest rate by compounding all operating profits to their future values at the end of the period.

¹ It should be worthwhile to mention that Broll and Wong (2015) explicitly model ambiguity for an exporting firm that sells in both the home country and a foreign country under 'smooth ambiguity aversion' a 'la Klibanoff et al. (2005). However, our paper uses the simplest possible analytical framework without modelling ambiguity aversion using simple portfolio theory to illustrate the risk-taking behaviour, not only for the similar type of exporting firm, but also for another type of risk averse firm that produces for the domestic market, using imported input from abroad.

The spot exchange rate is expressed in units of the home currency per unit of foreign currency. The foreign spot exchange rate, \tilde{e} is random,² being distributed according to an objective cumulative distribution function over support $[\underline{e}, \bar{e}]$. p_x is the per-unit price of exportable (x) in units of foreign currency; while p_y is the per-unit price of the product (y) sold in domestic market, in units of domestic currency. We assume that the firm is price-taker in both domestic and foreign markets.

With total output $q = x + y$, the random operating profit of the firm is given by

$$\tilde{\Pi} = \tilde{e}p_x x + p_y y - C(x + y).$$

The domestic firm's preferences are given by a two-parameter utility function

$$V = V(\mu, \sigma). \tag{1}$$

Where $\mu = \mu_e p_x x + p_y y - C(x + y)$ and $\sigma = \sigma_e p_x x$ denote, respectively, the expected value and the standard deviation of random profit.

To have a non-trivial decision problem, we assume that $\underline{e}p_x < p_y < \bar{e}p_x$. We require the following properties to be satisfied for all μ, σ : $V_\mu(\mu, \sigma) > 0$, $V_\sigma(\mu, \sigma) < 0$.

The marginal rate of substitution (MRS) between risk and return is defined by

$$S = - \frac{V_\sigma(\mu, \sigma)}{V_\mu(\mu, \sigma)}.$$

S is the two-parameter equivalent to Arrow-Pratt measure of absolute risk aversion. Indifference curves in (σ, μ) -space are upward-sloping, with their slopes measuring risk aversion.

The domestic firm solves the following problem

$$\max_{x \geq 0, y \geq 0} V(\mu(x, y), \sigma(x, y)). \tag{2}$$

² All random variables are denoted by a tilde ($\tilde{}$), while their realisations are not.

When we consider interior solutions of this decision problem, the optimum is then determined by

$$V_{\mu}(\mu^*, \sigma^*)(\mu_e p_x - C'(x^* + y^*)) + V_{\sigma}(\mu^*, \sigma^*)\sigma_e p_x = 0, \quad (3)$$

$$V_{\mu}(\mu^*, \sigma^*)(p_y - C'(x^* + y^*)) = 0. \quad (4)$$

The second-order condition is satisfied due to the quasi-concavity of $V(\mu, \sigma)$. In the optimum we obtain for total production $C'(x^* + y^*) = p_y$. However, the allocation of production depends on the firm's risk preferences.

The comparative static properties of the model are described *in relative terms*, how sensitively the firm's risk aversion responds to changes in expected final profit and risk.

1.1 Comparative statics

We are interested in how optimal risk taking behaviour of the exporting firm responds to changes in the world market. The comparative statics results predicts the impact of changes in the distribution of the (foreign) spot exchange rate.

Definitions. The elasticity of the marginal rate of substitution between risk and return *with respect to the standard deviation of the firm's end of period profit* is

$$\epsilon_{\sigma}(\mu, \sigma) = \frac{\partial S(\mu, \sigma)}{\partial \sigma} \frac{\sigma}{S(\mu, \sigma)}, \sigma > 0.$$

Similarly, elasticity of the marginal rate of substitution between risk and return *with respect to the mean of final operating profit* is defined as

$$\epsilon_{\mu}(\mu, \sigma) = \frac{\partial S(\mu, \sigma)}{\partial \mu} \frac{\mu}{S(\mu, \sigma)}.$$

By using the marginal rate of substitution, $S(\mu, \sigma)$, the first-order condition of the firm's international trade problem becomes

$$-\frac{V_{\sigma}(\mu, \sigma)}{V_{\mu}(\mu, \sigma)} = \left(\mu_e p_x - C'(x^* + y^*) \right) / p_x \sigma_e = S^*(\mu(x^*, y^*), \sigma(x^*, y^*)). \quad (5)$$

MRS (S) equal to the *slope of the opportunity* line. The left hand side of Equation (5) is merely the expected markup for exporting. Thus, when the expected markup is nonpositive, the firm will never export some of its production.

Using Equation (5), Broll and Mukherjee (2016) shows

$$\left(\frac{\partial x^*}{\partial \sigma_e} \right) > 0, \text{ iff } \epsilon_{\sigma}(\mu(x^*, y^*), \sigma(x^*, y^*)) < -1, \text{ ceteris paribus.} \quad (6)$$

In other words, a risk-averse exporting firm may increase its optimal export x^* upon an increase in risk, σ_e , if and only if the risk aversion elasticity is less than -1 , i.e., $\epsilon_{\sigma}(\mu^*, \sigma^*) < -1$.

An increase in revenue risk (brought about by the uncertain exchange rate movements in the world market) leads to a ***substitution effect and an income effect (or wealth effect)***. If the firm has *decreasing absolute risk aversion* an increase in σ_e makes the firm 'poorer', the firm behaves in a *more risk aversion fashion* and *supplies less export*. Thus, the total effect on export supply depends on the *relative magnitudes* of the *income and substitution effects*.

Now we examine the relationship between the firm's export and domestic sales with respect to a change in the expected foreign exchange rate, i.e., μ_e . As Broll & Mukherjee (2016) shows

$$\left(\frac{\partial x^*}{\partial \mu_e} \right) > 0, \text{ iff } \epsilon_{\mu}(\mu(x^*, y^*), \sigma(x^*, y^*)) < 1, \text{ ceteris paribus.} \quad (7)$$

Owing to an increase in the expected foreign exchange rate at a given risk, a risk-averse exporting firm may optimally increase export at the intensive margin if and only if the elasticity of the marginal rate of substitution between risk and return with respect to μ is less than 1, i.e., $\epsilon_{\mu} < 1$.

To sum up, our results can be generalised by stating that the firms with sufficient financial resources and therefore, with greater risk-taking capacity may not necessarily reduce exports at the intensive margin owing to the exchange rate risks. This explains the asymmetries in the responses of different firms on their export activities to the fluctuations in foreign exchange rate.

2. Quantitative Analysis

We describe an empirical analysis for an estimation of an international firm's preferences and technology under mean–standard deviation approach of final profit. We apply the following specific utility function (Saha 1997)

$$V(\mu, \sigma) = \mu^a - \sigma^b \quad (8)$$

Where a and b are parameters. Therefore the firm's risk attitude is

$$S^*(.) = \frac{b}{a} \mu(x^*, y^*)^{1-a} \sigma(x^*, y^*)^{b-1} \quad (9)$$

Using Equation (9) it is easy to infer

$$\ln S_{it}^* = \ln \left(\frac{b}{a} \right) + (1 - a) \ln \mu_i + (b - 1) \ln \sigma_i \quad (10)$$

Hence we obtain

$$\epsilon_{\sigma}(\mu(x^*, y^*), \sigma(x^*, y^*)) = (b - 1) \quad (10.1)$$

$$\epsilon_{\mu}(\mu(x^*, y^*), \sigma(x^*, y^*)) = (1 - a) \quad (10.2)$$

Propositions (1) implies iff $(b - 1) < -1$ then only firm's optimum export increases when the revenue risk increases owing to greater volatility in the foreign exchange rate. Similarly Proposition (2) implies the firm will optimally export more when expected revenue increases iff $(1 - a) < 1$.

Hence we are going to estimate $(b - 1)$ and $(1 - a)$ for different non-financial service sector exporting Indian firms over 2004-2015. Consequently, our purpose should be to study the entire conditional distribution of S , the risk-attitude of the firms. Hence we apply Quantile Regression.

Equation (10) allows us to estimate the following unique structural estimation equation:

$$\ln S_{it} = \beta_1 + \beta_2 \ln \mu_i + \beta_3 \ln \sigma_i + \varphi \gamma_t + \varepsilon_{it} \quad (11)$$

Hence we are going to estimate $\beta_2 (= (1 - a))$ and $\beta_3 (= (b - 1))$ at different points of the entire conditional distribution of S , the risk-attitude of the firms. Hence we apply quantile regression (Koenker 2005) for different non-financial service sector exporting Indian firms over 2004-2015. This is a widely used estimation technique when it comes to examining the impact of explanatory variables at different points of the distribution of the dependent variable. Standard OLS techniques concentrate on estimating the mean of the dependent variable subject to the values of the explanatory variables. Usually, variables are included as uncentred regressors. Quantile regression allows us to centre the regressor around different quantiles (for example, regressors are centred around the median at the 0.5 quantile). This adds value to estimation results, especially in the context of distribution of risk preferences. Given a set of explanatory variables, quantile regression estimates the dependent variable conditional on the selected quantile. Once the coefficients are estimated, standard errors are generated by bootstrap replications to avoid imposing distributional assumptions which is also one of the advantages of estimating a quantile regression.

2.1 Data and Variables

We use a panel data for 85 “exporting non-financial service sector firms” operating 2004-2015 (not comprising ‘switching-in-and-out’ firms within this time-period) from *Prowess IQ Database* of CMIE.

S_{it}^* : Firm’s attitude towards risks arising from exchange rate volatilities at the firm level; measured as $(\text{Financial Vulnerability})_{it} \times (\text{REER Volatility})_t$.

“Financial Vulnerability” is measured as ratios of firms’ net fixed assets to total assets, captures a firm’s reliance on the external sources of financing (Cheung & Sengupta 2013) & thereby vulnerability of a firm to external shocks. REER Volatility (σ_e) is computed as the yearly standard deviation of monthly log differences in the real exchange rate (**Source**: RBI Statistics); (Héricourt & Poncet 2014).

μ_i (expected relative net profit) is measured as the “predicted” net profit to the mean profit at the firm-level = $\left(\frac{\widehat{M}_t}{M_t}\right)_i$ (Schmidt & Broll 2009).

σ_i measures the standard deviation of the (log of) net profit.

2.2. Empirical Results

The risk attitude of these firms towards foreign exchange rate fluctuations, on the overall basis exhibits two broad patterns:

- $b \neq 0$ at any quantile of the risk-distribution. So *no firm in our sample is risk-neutral*. Furthermore, $-b/\alpha$ is significantly greater than 1 up to 70th quantile, implying *increasing relative risk aversion up to 70th quantile & then decreasing relative risk aversion*. Also *no evidence of constant relative risk aversion* as $-b/\alpha$ is significantly different from unity.
- $\epsilon_\sigma = (b - 1) > -1$ and $\epsilon_\mu = (1 - a) < 1$. Hence $\left(\frac{\partial x_{it}}{\partial \sigma_e}\right) < 0$, but $\left(\frac{\partial x_{it}}{\partial \mu_e}\right) > 0 \Rightarrow$ *Decreasing absolute risk aversion (DARA)*.

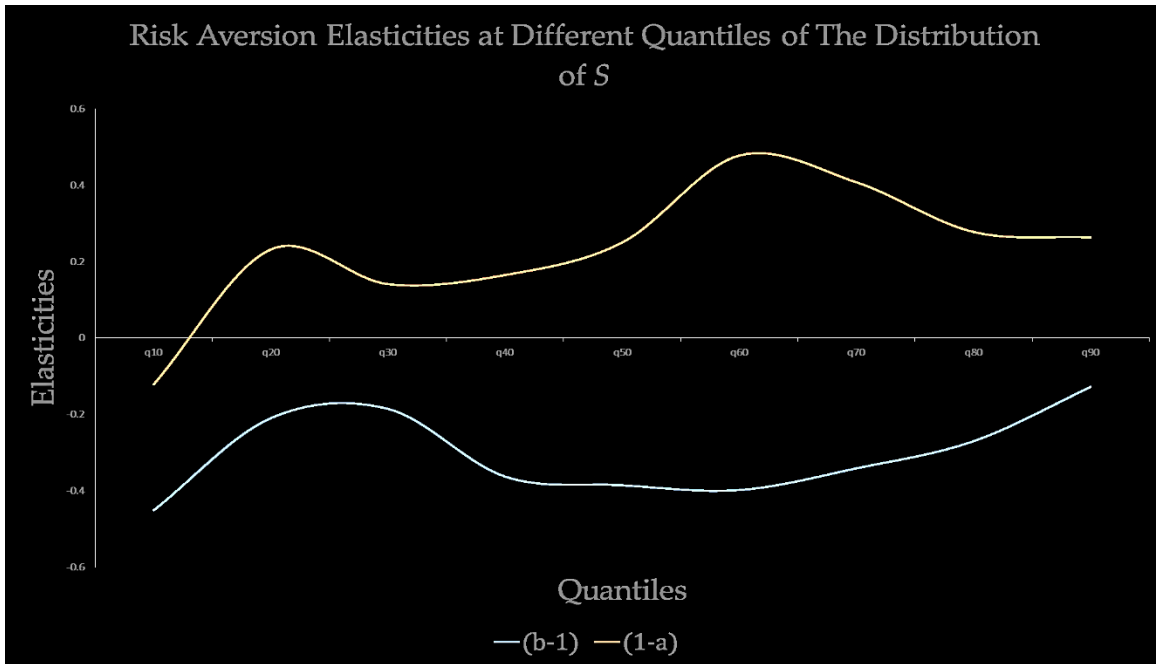
However, ϵ_σ is the lowest at the 10th quantile of the risk-distribution. It follows an inverted-U-shaped path up to the 40th quantile & becomes more-or-less stable up to the 60th quantile of the risk-distribution; but sharply increases after that.

Interestingly, for ϵ_μ , we observe two humps in the distribution: the first is at the 20th quantile & the next is at the 60th quantile of the risk-distribution.

Table 1: Quantile Regression Results (Full Sample)

Note: **, *, + are respectively denoting levels of statistical significance at 1%, 5% and 10% levels; standard errors are in parentheses.

Dependent Variable: <i>S</i>	10%	20%	30%	40%	50%	60%	70%	80%	90%
μ	-0.121 (0.160)	0.232** (0.085)	0.141* (0.068)	0.165** (0.062)	0.250** (0.076)	0.478** (0.100)	0.408** (0.067)	0.278** (0.068)	0.263** (0.051)
σ	-0.451** (0.132)	-0.210 (0.149)	-0.186 (0.127)	-0.363* (0.086)	-0.386** (0.099)	-0.398** (0.097)	-0.341** (0.098)	-0.270** (0.077)	-0.128* (0.051)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
b/a	-3.016** (0.176)	-2.527** (0.123)	-2.118** (0.121)	-2.009** (0.126)	-1.713** (0.164)	-1.506** (0.202)	-1.135** (0.214)	-0.784** (0.054)	-0.680** (0.083)
Observations	1008	1008	1008	1008	1008	1008	1008	1008	1008
Pseudo R^2	0.081	0.075	0.088	0.098	0.107	0.116	0.132	0.159	0.212
Testing equality of coefficients: F -Stat (Prob > F)									
10% (13, 994)		1.65 ⁺	2.35**	1.34	0.89	2.11**	1.84*	2.48**	2.93**
20% (13, 994)			2.46**	2.14**	2.20**	0.97	1.10	0.90	1.40 ⁺
30% (13, 994)				2.51**	2.25**	3.71**	7.43**	3.61**	3.73**
40% (13, 994)					6.38**	5.45**	2.43**	5.34**	2.67**
50% (13, 994)						1.50 ⁺	5.17**	2.42**	5.09**
60% (13, 994)							0.62	5.63**	11.49**
70% (13, 994)								5.92**	12.85**
80% (13, 994)									1.19



Increase in expected foreign exchange rate (INR/US Dollar) has encouraged all the firms in our sample to increase the exports over 2004-2015. But the responsiveness still varies across the firms as ϵ_{μ} is different for different firms (with two humps in the distribution for $(1 - a)$). This is explained by the interplay between firm-specific substitution and income effects of the risk-taking capacity, which is, in turn, guided by the extent of the financial constraints faced by different firms in our sample (whether the firm uses its own assets as collateral or borrows externally when exchange rate fluctuates).

3. Summary

This is the first attempt to quantitatively link the asymmetries in firms' differential export behaviour, owing to the unprecedented exchange rate movements, to the risk attitude of the firms, by explicitly estimating risk aversion elasticities.

All the Indian (non-financial) service sector firms in our sample seem to have *positive association* to the changes in the *expected REER change*, but *negative association* to the changes in the *REER volatility* during 2004-2015. They exhibit DARA in general.

However, the risk aversion elasticities seem to vary across firms, which points out towards the interplay between firm-specific substitution & income effects of the risk-taking capacity that is guided by the extent of the financial constraints faced by different firms in our sample.

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