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Abstract[1]

This paper estimates the impact of relative price volatility on sector-level investment allocation using a panel of 65 countries with data for 26 manufacturing industries over the period 1985-2003. Results indicate that volatility distorts efficient investment allocation in that investment is not necessarily devoted to relatively more productive sectors, especially in emerging market economies that are highly exposed and may lack the necessary institutions to deal with it successfully. This is evidence in support of theories suggesting that relative price volatility provides incentives for entrepreneurs to adopt more "malleable" but less productive production technologies, enabling them to accommodate more easily abrupt and frequent changes in relative prices, but at the cost of using less productive technologies.

JEL classifications: D24, E22, O31, L60.
Keywords: Sector-level TFP, Relative price volatility, Investment allocation, Financial crises, Emerging markets, Malleable technologies.

[1] The paper represents the views of the authors and do not necessarily reflect the views of any institution including the IDB, its Executive Directors or the countries they represent. We thank Alberto Chong for comments on a previous version. All remaining errors are our own.

1. Introduction

A key characteristic of economies faced with systemic financial crises is their exposure to dramatic real exchange rate fluctuations.[2] The empirical cross-country evidence suggests that real exchange rate volatility has a significant impact on aggregate total factor productivity growth (TFP).[3] In this paper we provide new evidence on possible transmission mechanisms from relative price volatility to TFP. In particular, using sector-level panel data, we show that volatility may distort the *efficient* allocation of investment across sectors, especially in countries where relative price volatility is more prevalent.

Doing business in an economy that is periodically exposed to turmoil in relative prices means that entrepreneurs must face substantial uncertainty about the profitability of alternative projects. Under this scenario, a key feature is the ability to adapt to a volatile environment. One influential strand of the investment literature suggests that volatility, coupled with irreversibility (i.e., the notion that once certain investments are undertaken, installed capital has little value for alternative uses), increases the expected return required for an investment to materialize.[4] Available cross-country empirical evidence is supportive of this view.[5] Moreover, relative price volatility associated with financial crises has been shown to be a determinant of investment collapses in developing countries.[6]

However, volatility affects economic growth not only through its direct impact on lowering investment, but can also harm productivity growth by affecting the efficiency of investment allocation. The link between volatility and productivity relies on how volatility may affect choices made about the type of investment projects selected vis-à-vis those that fail to materialize. For example, if volatility discourages disproportionally more certain types of investments that are associated to higher innovation (ranging from the invention of new products to making a given technology more efficient), then TFP may take a hit.[7] Even if innovation is not

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[2] See for example, Calvo, Izquierdo and Mejía (2008).
[3] See, for example, Aghion et al. (2009).
[4] See Pindyck and Solimano (1993) and Dixit and Pindyck (1994) for seminal contributions to this literature.
[5] Although the theoretical literature shows that under different assumptions the sign of the relationship between volatility and investment is ambiguous (i.e., Abel and Eberly, 1994, vs. Aizenman and Marion, 1999), the empirical literature has found a robust negative effect (Pindyck and Solimano, 1993; Demir, 2009a and 2009b; Servén 2003).
[6] In particular, this is more prevalent in financially integrated emerging markets. See Joyce and Nabar (2009)
[7] This is because if the creation of new activities is important for sustained productivity growth, as has been suggested in the endogenous growth (see Aghion and Howitt, 1998) and the self-discovery literatures (see Hausmann and Rodrik, 2003) respectively, then volatility that hinders innovation may ultimately reduce average

an issue, to the extent that more efficient technologies require a higher degree of specialization, thus reducing flexibility to switch across activities using the same equipment, relative price volatility may introduce distortions in the sectoral allocation of investment.

While all countries face some degree of volatility, emerging markets in particular have been subject to a history of international financial crises and volatility in relative prices. A key characteristic of economies faced with large capital inflows and subsequent crises is their exposure to dramatic real exchange rate fluctuations. For example, Calvo, Izquierdo and Mejía (2008) find that almost three-fourths of large real exchange rate depreciation episodes in emerging markets are linked to sudden cuts in the capital account. When this happens, current account deficits must be curtailed as there is no more financing for them. In equilibrium, this is attained through a large depreciation of the real exchange rate. However, previous to capital account disruptions, many of these economies typically undergo large capital inflow episodes accompanied by large real exchange rate appreciation. Economies that are intermittently exposed to such relative price volatility face substantial uncertainty about the profitability of investment projects, and entrepreneurs may find it optimal to select technologies that are easily reversed, i.e. that are more malleable.[8]

However, greater malleability may not be costless, given that constantly jumping from one task to another may prevent the discovery of more efficient methods of production. Calvo (2005) formalizes this idea. He develops a simple model that explores the effects of relative price volatility in entrepreneurs' incentives to undertake certain investment projects over others. The basic idea is that volatility may induce producers to adopt "malleable technologies," permitting them to change from one line of production to another with a minimum of stress at the expense of lower productivity. Implicit is the idea that specialization and focusing on narrow tasks are conducive to greater innovation or productive efficiency. As a result, more specialized, less malleable technologies will tend to be more productive.

Despite the strong intuitive appeal of Calvo's model, empirical validation has remained elusive. Embedded in his arguments is the idea that volatility affects the allocation of investment

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productivity growth. Aizenman and Marion (1999) provide an explanation for the reluctance of entrepreneurs to embark on new activities in the presence of volatility.

[8] This idea has been identified long ago in the Latin American and the Caribbean literature as a case of "speculative production," in that entrepreneurs, constantly speculating on relative price volatility, pick technologies that make it easy to switch from one product to the next. One of the clearest examples is that of the agricultural sector, which may quickly switch from one crop to the next depending on relative prices. See Ocampo (1984).

across different economic sectors. Goldberg and Kolstad (1995) study the effect of exchange rate volatility on the allocation of foreign direct investment.[9] However, their work is not otherwise related to Calvo's model as it does not relate the location of investment to the underlying productivity of technologies.

Instead, Demir (2009b) takes the stance of associating "malleable technologies" with investment in financial assets while "productive technologies" are associated with fixed capital investment.[10] Using firm-level data for a sample of three developing countries, he does not find a homogeneous empirical relationship between volatility and investment allocation across these categories. Arza (2008) explores the effects of general macroeconomic volatility on investment in machinery and investment in R&D using micro data for Argentina during the period 1992-2000. While she finds evidence of a negative impact of volatility on both types of investment, she does not explore allocation effects.

Although malleability is difficult to assess empirically, a shortcut is to consider capital intensity relative to labor as a proxy for inflexibility, under the assumption that labor is easier to reallocate than capital, which tends to be more specific to a particular production process. Figure 1 (figures and tables appear following the text) shows the relationship between an index of the capital-labor ratio and an index of TFP for a world sample of industrial sectors coming from UNIDO (2008). It indicates that more capital intensive (probably less malleable technologies) are associated with higher TFP levels—the correlation between these two variables is 0.5—supporting the view that more inflexible production technologies could in fact be more productive. Taking this as an assumption, we explore what is the efficient allocation of investment across sectors in the context of a simple framework that relates sector-level investment to the underlying productivity of technologies. We show that in the absence of economic frictions and relative price volatility, investment allocation across economic sectors should be positively related to the underlying relative productivity of technologies. If this is the case, the existence of volatility could bias investment choices into technologies that are less productive but highly malleable. To the extent that expected volatility remains a cloud parked in

[9] They show using two-way bilateral foreign direct investment flows data for four industrialized countries that exchange rate volatility tends to stimulate the share of investment activity located in foreign soil

[10] Tornell (1990) argues that given the uncertain environment in developing countries, real sector firms may prefer to invest in more liquid reversible assets in the financial sector rather than on irreversible fixed assets.

the investment horizon, economies could remain stuck in less productive environments than those of less volatile peers.

The main contribution of our paper is to provide a new approach to test the impact of relative price volatility on investment allocation. One point of departure with respect to previous efforts is that we use sector level data to exploit TFP heterogeneity within the manufacturing sector. We take from Calvo (2005) the idea that relative price volatility conspires against the choice of more productive technologies, and from Goldberg and Kolstad (1995) the idea that volatility affects the composition of investment and ask: can relative price volatility affect sectoral allocation of investment away from what TFP differences would indicate? Our research concludes that the answer is affirmative for the case of emerging market economies. Interestingly, this result is consistent with recent findings showing that emerging markets—which in terms of financial integration stand in between developing and developed countries but may lack the necessary institutions to ensure financial stability—are the most exposed to Sudden Stops and are therefore the most likely to be subject to substantial real exchange rate volatility stemming from financial shocks.[11]

The structure of the paper is as follows: Section 2 provides a conceptual framework linking investment allocation to the underlying productivity of economic sectors. Section 3 describes the methodology and the data. Section 4 shows results, and Section 5 provides robustness checks. Finally, conclusions are given in Section 6.

2. Conceptual Framework

In order to proceed empirically, it is first necessary to understand the relationship between sectoral investment shares and relative TFP. The simple framework introduced next clarifies this point, and it represents a benchmark indicating efficient investment allocation in the absence of relative price volatility. It will be used later on in the empirical section as a departure point against which the effects of volatility can be contrasted.

Consider the case of a representative firm that seeks to maximize profits (Π) by choosing optimal capital allocation in the production of two different goods. Good 1 has a production technology given by $a_1 f(k_1)$, where a_1 is represents TFP, and k_1 is capital allocated to the

[11] See Calvo, Izquierdo and Mejía (2008).

production of good 1. Good 2 has a similar production technology, which differs only in its productivity level, represented by a_2. Thus, the firm's maximization problem can be written as:

$$Max_{k_1,k_2}\ \Pi = a_1 f(k_1) + pa_2 f(k_2) - r(k_1 + k_2),$$

where *r* is the rental rate of capital, and *p* is the price of good 2 (in terms of good 1). First order conditions for this problem are given by:

$$a_1 f'(k_1) = r \tag{1}$$

$$pa_2 f'(k_2) = r \tag{2}$$

Assuming production functions are homogeneous of degree *n*, and using Euler's theorem for homogeneous functions, the following holds:

$$f'(k_1)k_1 = nf(k_1), \tag{3}$$

$$f'(k_2)k_2 = nf(k_2). \tag{4}$$

Combining (1)-(3) and (2)-(4), and solving for k_1 and k_2 yields:

$$k_1 = \frac{1}{r} na_1 f(k_1); \tag{5}$$

$$k_2 = \frac{1}{r} na_2 pf(k_2); \tag{6}$$

Making use of equations (5) and (6), the share of investment in sector 1 (k_1) relative to total investment ($k_1 + k_2$) can be rewritten as:

$$\frac{k_1}{k_1 + k_2} = \frac{a_1}{a_1 + pa_2 \dfrac{f(k_2)}{f(k_1)}} = \frac{1}{1 + p\dfrac{a_2 f(k_2)}{a_1 f(k_1)}} \tag{7}$$

From (7) it can be easily verified that the share of investment in the production of good 1 relative to total investment depends positively on relative TFP of good 1 vis-à-vis a weighted sum of TFPs of good 1 and good 2 (see the second term in equation (7)). This framework can be extended to incorporate *n* goods, in which case the weighted sum is extended to include additional terms showing TFPs of any additional goods. In more general terms, equation (7) could be written as:

$$\frac{k_1}{\sum_{i=1}^{n} k_i} = \frac{a_1}{a_1 + \sum_{j=2}^{n} w_j a_j}, \tag{8}$$

where w_j represent weights given by the second term in equation (7). For the particular case analyzing two goods, it is clear from equation (7) that the share of investment in good 1 in total investment depends positively on relative TFP of good 1 vis-à-vis that of good 2, or the ratio $\frac{a_1}{a_2}$.

In summary, in the absence of economic frictions, investment allocation across economic sectors should be positively related to underlying productivity. In particular, we would expect to observe higher investment going to sectors with relatively higher TFP. The question that will be asked in the empirical section is how much the relationship described in (8) is altered with the introduction of relative price volatility. As mentioned in the introduction, large capital inflow processes and subsequent disruptions in international credit markets, a common factor in emerging economies, affect a key relative price, namely, the real exchange rate. However, the effect of real exchange rate volatility on sectoral investment allocation is not clear. For instance, to the extent that more productive sectors are basically tradable but their production technologies are less malleable, then large real exchange rate volatility may affect those sectors disproportionately in terms of the uncertainty of profits derived from investment in those sectors. However, these characteristics may not necessarily hold in tandem to validate such an explanation. Therefore, we address this question from an empirical perspective in the next section.

3. Methodology and Data

Relative price volatility may reduce the ability of countries to allocate resources efficiently. In an ideal frictionless world with little uncertainty, resources should be allocated more intensively towards activities where productivity is the highest. High volatility exacerbates uncertainty and may lead to allocation decisions that may remain optimal from a private point of view, but that deviate from a socially optimal environment of low volatility. We test for the existence of these potential allocation effects of relative price volatility by exploring how the share of investment received by each sector in a country matches that sector's relative productivity, and how that relationship changes under different scenarios of volatility.

Based on the framework subsumed in equation (8) of the previous section, we estimate regressions of the following type:

$$\frac{I_{ijt}}{\overline{I_{jt}}} = \gamma_1 \frac{TFP_{ijt-1}}{\overline{TFP_{jt-1}}} + \gamma_2 \frac{TFP_{ijt-1}}{\overline{TFP_{jt-1}}} \cdot \sigma_{jt-1} + \mu_{jt} + \nu_{it} + \varepsilon_{ijt} \qquad (9)$$

where *i*,*j* and t denote a sector, a country, and year respectively, I_{ijt} is investment in sector *i* in country *j* at time *t*, $\overline{I_{jt}}$ is total investment in country *j* at time *t* ($\overline{I_{jt}} = \sum_i I_{ijt}$), and TFP_{ijt} is a measure of total factor productivity of sector *i* in country *j* at time *t*. $\overline{TFP_{jt}}$ is a proxy of the denominator of equation (8) given by the simple sum of total factor productivities of all sectors in country *j* at time *t*.[12] σ measures relative price volatility. Finally, μ and ν are country-time and industry-time fixed effects. These dummy variables control for all possible observable and unobservable components that vary at a country-time and sector-time level, respectively, reducing the need for additional control variables.

It is worth noting that the ratio of TFP of sector *i* of country *j* in equation (9) is lagged. The analysis above suggests that the TFP ratio is predetermined, and that investment decisions are made based on the observation of productivity across sectors. That is, it assumes that the TFP ratio is exogenous. If productive enhancements are imbedded in capital goods, it is likely that investment will affect TFP. If this is the case, and if it happens contemporaneously, the estimation of equation (9) would be subject to biases due to this type of endogeneity. We deal with this potential problem in two ways. First, we estimate (9) by OLS while lagging the TFP ratio by one year and, second, we estimate (9) using an IV estimator. In the latter we use the second year lag of the TFP ratio as an instrument. The IV estimator is used in case the first lag does not remove endogeneity completely.

Similarly, the country-specific volatility measure (σ) is also lagged in equation (9), as we assume that investment decisions are made based on the observation of prevailing volatility in

[12] Given lack of data on relative prices it was not possible to construct weights as suggested by equation (8). Thus, the first term on the right-hand side of equation (9) was constructed as the share of TFP in sector *i* of country *j* at time *t* in the simple sum of TFPs of all sectors of country *j* at time *t*.

the economy before investment decisions are made (i.e., volatility is also predetermined). However, it is well known that volatility does not affect all countries uniformly.[13] For that reason, we allow for differential effects across well-identified country groupings: advanced and developing countries. For the last group of countries, we further distinguish between emerging market economies, which are the subset of countries integrated to world capital markets, and other developing economies which are less integrated into capital markets.

The main test conducted in this paper is on the sign and significance of the coefficients γ_1 and γ_2, both for the whole sample of countries, as well as for the three groups of countries described above. In advanced economies, where financial frictions are less common and macroeconomic environment is relatively stable, we expect a positive relationship between the share of investment in each economic sector and relative productivity of the sector (as predicted by the model presented in the previous section), and also that macro volatility will be less of an issue (i.e., $\gamma_1 > 0$ and $\gamma_2 = 0$). For other types of countries, where financial frictions abound and systemic crises are common, we expect that the connection between TFP shares and investment allocation will be weaker (i.e., $\gamma_1 = 0$) and/or that volatility will distort the efficient allocation of investment (i.e., $\gamma_2 < 0$). In other words, as volatility increases, the estimated relationship between the dependent variable and sectoral relative TFP should weaken, meaning that γ_2 is negative.

Equation (9) is estimated using a panel of yearly data for 26 manufacturing industries in 65 countries for the timeframe 1985-2003. The complete list of countries with their corresponding groups is shown in Appendix 1. The main source of data is the United Nations Industrial Development Organization database (UNIDO, 2008). We exploit information available at the cross-country, industry and time dimensions on investment, number of employees, and value-added to construct ratios of sectoral investment to total investment and the proxies of total factor productivity (TFP) needed to construct the ratios shown in equation (9).[14]

Appendix 2 describes how TFP measures are constructed. Here, it suffices to say that TFP is constructed by a cost shares approach. A Cobb-Douglas production function in labor and capital is assumed. The production function is log-linearized and TFP is computed as the

[13] Countries at different income levels, degrees of integration to world markets and development of local financial markets, have different means to deal with volatility (see Aizenman and Pinto, 2005).
[14] Investment and value added are in current US dollars.

accounting difference between output and a linear combination of the inputs with cost shares varying between industries but remaining constant across countries.

Computation of the investment ratio is straightforward. Using data on gross fixed capital formation from UNIDO (2008) for each sector in each country and for each time period, the investment ratio is calculated as the share of investment in a specific country-sector in the sum of investment across sectors in that country (aggregate investment).

Baseline regressions use the volatility of the yearly change in the real exchange rate of each country as the proxy for relative price volatility.[15] We compute the real exchange rate as a bilateral real exchange rate of each country with respect to the United States. Consumer price indexes are used for the computation of the real exchange rate.[16] Volatility is measured as the standard deviation of the twelve month change in the logarithm of the bilateral real exchange rate index in a 60 month period. Alternative measures are used for robustness checks.

4. Results

Columns (1) and (2) of Table 1, report baseline results of the estimation of equation (9) by OLS and IV for the whole sample of countries. Interestingly, these results suggest that neither the TFP ratio (i.e., coefficient γ_1) nor the TFP ratio interacted with the measure of relative price volatility (i.e., coefficient γ_2) are statistically significant.

In order to explore this result further, the next logical step is to allow coefficients attached to the relevant explanatory variables to vary across different types of countries. This seems a natural avenue to explore due to the large heterogeneity among countries in the sample. As shown in Appendix 1, the sample includes a mix of industrialized countries, developing countries with high penetration in international capital markets (emerging), and developing countries with low participation in global capital markets (non-emerging). As explained before, these groups of countries differ in several dimensions, including their level of volatility, their macroeconomic management, and the quality of their institutions, among others.

To take these differences into account we estimate the following variation of equation (9):

[15] The data used to construct these measures comes from the International Financial Statistics of the IMF.
[16] The real exchange rate is defined as: $RER_i = P_{USx}ER_i/P_i$. Where ER_i is the nominal exchange rate of country *i* with respect to the US, and P_{US} and P_i are the consumer price indexes of the US and country *i* respectively.

$$\frac{I_{ijt}}{I_{jt}} = \sum_{k=\{A,E,N\}} \left(\gamma_1^k \frac{TFP_{ijt-1}}{TFP_{jt-1}} + \gamma_2^k \frac{TFP_{ijt-1}}{TFP_{jt-1}} \cdot \sigma_{jt-1} \right) \cdot I_{\{k\}} + \mu_{jt} + \nu_{it} + \varepsilon_{ijt} \qquad (10)$$

where $I_{\{k\}}$ is an indicator function pointing whether a country is an advanced economy (A), a developing country with high penetration in global capital markets (E), or a developing country with little penetration in capital markets (N), respectively. Developing countries are split into the last two groups on the basis of whether they are included in JP Morgan's Emerging Markets Bond Index (EMBI).

Results of estimating equation (10) using OLS and IV are reported in columns (3) and (4) of Table 1. Results are robust across both specifications and suggest that in fact there are relevant differences across groups of countries. In line with our priors, in both specifications coefficient γ_1 is positive and significant for advanced and emerging economies only, while γ_2 is negative and significant for emerging economies, but is not significant for advanced or non-emerging economies.[17]

This result attests to the fact that volatility in emerging countries affects the efficiency with which investment is allocated. It seems that volatility hurts particularly in countries that, while integrated to international capital markets, may lack sufficient institutional arrangements to cope with volatility. This result has an analogous counterpart in recent findings that relate the probability of facing a Sudden Stop in capital flows—a major culprit for real exchange rate volatility—to levels of financial integration.[18] Countries with low levels of financial integration have a small probability of facing a Sudden Stop, but so do advanced countries that, while being vastly integrated, possess sophisticated volatility-coping weaponry. However, emerging markets, with higher levels of financial integration than developing countries but more precarious volatility-coping mechanisms than developed countries, face the highest probability of a financial crisis and, as such, are much more exposed to real exchange rate fluctuations stemming from financial turmoil. Of course, this does not mean that larger integration is necessarily bad. Quite to the contrary, recent literature has highlighted the benefits of larger integration despite

[17] This result is consistent with the findings of Galindo, Schiantarelli and Weiss (2007) who find that in emerging markets that are more financially liberalized, investment responds stronger to fundamentals at the firm level, but this relationship is weakened as macroeconomic instability increases.
[18] See Calvo, Izquierdo and Mejía (2008).

increased proneness to crisis.[19] However, it implies that emerging markets are probably the most affected by real exchange rate volatility given the larger swings in capital flows that they face. The threat of living in an environment with potential volatility in the cards may lie behind the choice of less productive technologies and lower levels of average TFP vis-à-vis more stable regions.

These results are not only statistically significant; their economic impact is also relevant. To see this, and to visualize how the impact differs across groups of countries, Figure 2 plots the marginal impact of changes in the TFP ratio on investment shares for different levels of volatility and for each group of countries. The marginal impact is computed as:

$$\frac{\partial \frac{I_{ijt}}{I_{jt}}}{\partial \frac{TFP_{ijt-1}}{TFP_{jt-1}}} = \gamma_1^k + \gamma_2^k \sigma_{jt-1} \qquad (11)$$

where *k* denotes the group of countries for which the marginal impact is computed (A,E, or N). Figure 2 depicts equation (11) for the three groups of countries and for the range of volatilities that are relevant to each group, with appropriate confidence intervals.[20] Panel (a) plots the marginal effect of an increase in relative TFP on the investment share for advanced economies, panel (b) for emerging economies and panel (c) for non-emerging ones. Most notably, panel (a) suggests that the marginal effect of increasing relative TFP is always positive and significant in advanced economies, irrespective of the level of volatility. A one standard deviation increase in relative TFP for this group of countries (0.009), increases the investment share by nearly 2.6 percentage points. This number is significant given that the average investment share for this group of countries is 4.5 percent. The result that the impact does not change significantly for different levels of volatility maybe explained by the fact that volatility is very low in this group of countries (see Appendix 3) and that these economies have the means to deal with the existent volatility successfully.

[19] See for example, Rancière, Tornell and Westermann (2008).

[20] Note that the relevant standard error for the estimated marginal impact for each group of countries *k* is given by:

$$s^k = \sqrt{\text{var}(\gamma_1^k) + \text{var}(\gamma_2^k) * \sigma_{jt-1}^2 + 2\,\text{cov}(\gamma_1^k \gamma_2^k \sigma_{jt-1})}$$

Panel (b) shows that for emerging economies the impact of changes in relative TFP depends significantly on the level of volatility. The marginal impact is positive and significant up to a volatility value close to 0.2. This corresponds to nearly the 90th percentile of the distribution of the volatility measure in these economies. Hence we can conclude that for most levels of the volatility indicator there is a positive and significant relationship between relative TFP and investment shares, but the relationship is declining with the level of volatility, and once volatility reaches extreme values, the relationship vanishes. In other words, as volatility increases, investment in emerging economies is increasingly misallocated. For an emerging market economy with low volatility (0.0049), a one standard deviation rise in relative TFP (0.018), increases the investment share by 4.4 percentage points, while for another emerging market with average volatility (0.12), a one standard deviation rise in relative TFP, increases the investment share by 3.4 percentage points. Once again, these are important effects taking into consideration that the average investment share of a sector in these economies is 4.6 percent. However, the effect decreases with volatility until it finally vanishes when volatility surpasses the threshold value of 0.22.

Finally, panel (c) shows the marginal impact of increasing relative TFP in non emerging economies. Our results indicate that regardless of the level of volatility the impact is not significant. These economies are more volatile and there is more dispersion across countries than in the other subsets. The fact that volatility is higher can contribute to explain the non-significant relationship estimated above. High volatility—not only relative price volatility but macroeconomic volatility in general—affects the flow of information about the quality of projects to investors and hence distorts resource allocation.

In summary, the results suggest that relative price volatility affects the efficient allocation of investment across economic sectors. However, the result is not uniform for all countries. For advanced economies, where volatility is low and countries have the instruments to deal with it, there is no distortion. For emerging economies, which are prone to crises but that may lack sufficient institutional arrangements to cope with the ensuing relative price volatility, the distortions are prevalent. Finally, for other developing countries, we do not find any relationship between investment allocation and relative TFPs irrespective of volatility levels, which suggests that relative price volatility appears to be just one of many distortions that cloud the relationship between these variables in those economies.

5. Robustness Check

In order to test the robustness of these findings, different dimensions are explored, involving alternative measures of volatility and TFP, and a different model specification to account for possible persistence in investment shares.

First, alternative measures for relative price volatility are computed. In particular, two additional time-varying measures of volatility were constructed: the first one using a shorter two-year window, and another one using a fixed initial period and a varying time frame.[21] Keeping the initial valued fixed as opposed to using a rolling window may be relevant under the assumption that investors incorporate long memory in their decision making process.[22] Results for OLS and IV regressions are reported in Table 2.

Both the significance and size of the coefficients reported in Table 2 remain qualitatively unchanged with respect of those in Table 1.[23]

As additional robustness exercises we use different measures of volatility such as dummy variables for banking crises and systemic banking crises—from Caprio and Klingebiel (2003)—and currency crises—from Cerra and Saxena (2008). The results are reported in Table 3. For concreteness, we focus on the coefficient estimates for emerging countries only as this is the subset of countries for which these crises are more prevalent. In line with our previous results, we find that crisis volatility affects the efficiency with which investment is allocated.

Next, in Table 4 we test the robustness of the baseline results using an alternative measure of TFP based on fixed-cost shares. For this exercise we assume that the share of capital and labor is the same across all industries in all countries (see Appendix 2 for details). Once again, results for the OLS and IV models remain qualitatively unchanged.

Finally, we contemplate the possibility of model misspecification in (9) arising from the potential persistence of investment ratios over time. To account for this, we introduce the lagged dependent variable as an additional explanatory variable. Formally we estimate:

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[21] Since standard deviations are computed with monthly data and our regressions are done with yearly data, we take the 12-month average of the standard deviations as the measure for volatility in each year. The results that we report do not change when we take the figure of December of each year as the yearly figure.

[22] Descriptive statistics of these indicators as well as the rest of the variables used in the study are reported in appendix 3.

[23] A less strict volatility measure (not reported) was constructed with a 12-month window, and the baseline results do not change. Details available upon request.

$$\frac{I_{ijt}}{I_{jt}} = \rho \frac{I_{ijt-1}}{I_{jt-1}} + \gamma_1 \frac{TFP_{ijt-1}}{TFP_{jt-1}} + \gamma_2 \frac{TFP_{ijt-1}}{TFP_{jt-1}} * \sigma_{jt-1} + \mu_{jt} + \nu_{it} + \varepsilon_{it} \qquad (12)$$

The inclusion of a lagged dependent variable in the context of a panel with fixed effects is well known to generate biased and inconsistent estimators, since the lagged dependent variable, by construction, will be correlated with the error term. In order to deal with these issues, and following Arellano and Bond (1991) and Blundell and Bond (1998), we estimate (12) using a system GMM estimator. Due to the difficulty in implementing this specification for a large set of explanatory variables as in equation (10), rather than including interactive terms with country-type dummies, we estimate three regressions, one for each set of countries. Table 5 reports these results.[24]

For each set of countries, the lagged value of the investment ratio is significant, suggesting that investment composition is indeed highly persistent. Sectors that received a higher share of investment in the past are likely to retain their share in the future. It is important to point out that controlling for persistence in the investment ratio reduces the size of the coefficient of relative productivity (γ_1), which would be consistent with an underlying model in which the fixed costs of investment limit the ability of an economy to accommodate quickly to changes in the relative profitability of investment opportunities. But this does not change results regarding the effects of volatility on the allocation of investment. The sign and statistical significance of the coefficients that accompany the interaction of the TFP ratio and volatility (i.e., γ_2) remain unchanged.

6. Conclusions

This paper provides empirical support for the idea that volatility, in particular real exchange rate volatility, reduces entrepreneurs' incentives to adopt more productive but potentially less "malleable" technologies to minimize uncertainty associated with relative price fluctuations.[25]

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[24] Due to instruments proliferation and matrix convergence issues, results reported here correspond to split sample dynamic panel regressions. This approach differs from the previous estimation approach in that the calculation of industry-time effects is specific to each country grouping. We use the second and third lags of the variables in the model as instruments. The choice of instruments was validated by specification tests.

[25] As mentioned in Section 2, this could occur when more productive sectors are tradable sectors (an assumption in line with the literature) and their technologies are less malleable (as proxied by the positive correlation of the capital-labor ratio and TFP shown above). In this case, real exchange rate volatility will reduce relative allocation across these sectors, even if they are more profitable in the absence of real exchange rate volatility.

This is done by testing whether volatility affects the allocation of capital out of highly productive, potentially less malleable sectors. To the extent that expected volatility is a cloud on the investment horizon, economies could remain stuck in less productive environments than those of less volatile peers.

We use a panel of country-sector data for 65 countries spanning from 1985 to 2003 to test if volatility affects the relationship between sectoral investment shares in total investment and relative productivity. Our results suggests that investment shares and observed relative productivity are highly correlated in advanced economies, and poorly correlated in developing economies with little access to international capital markets, regardless of the level of relative price volatility. This is, in and of itself, evidence that countries that face higher levels of volatility (developing countries) are subject to a much higher degree of investment misallocation than countries where real exchange rate volatility is much lower (advanced economies).

For developing countries with access to international capital markets (emerging markets), that are also the countries with intermediate volatility in our sample, we find results that lie between the previous extreme cases. For most states of nature in terms of the level of volatility they face, there is a positive and significant relationship between investment allocation and relative productivity. However, this relationship fades as volatility increases. In cases where volatility exceeds the 90th percentile of the distribution, the relationship between relative TFP and investment becomes insignificant.

In short, we conclude that volatility hampers the efficient allocation of investment. High volatility biases investment towards ex ante less productive sectors. This result is robust to changes in the measure of TFP, changes in measures of volatility, and changes in estimation techniques.

Figure 1. TFP and Technology Flexibility as Measured by the Capital/labor Ratio (Industrial Sector Averages)

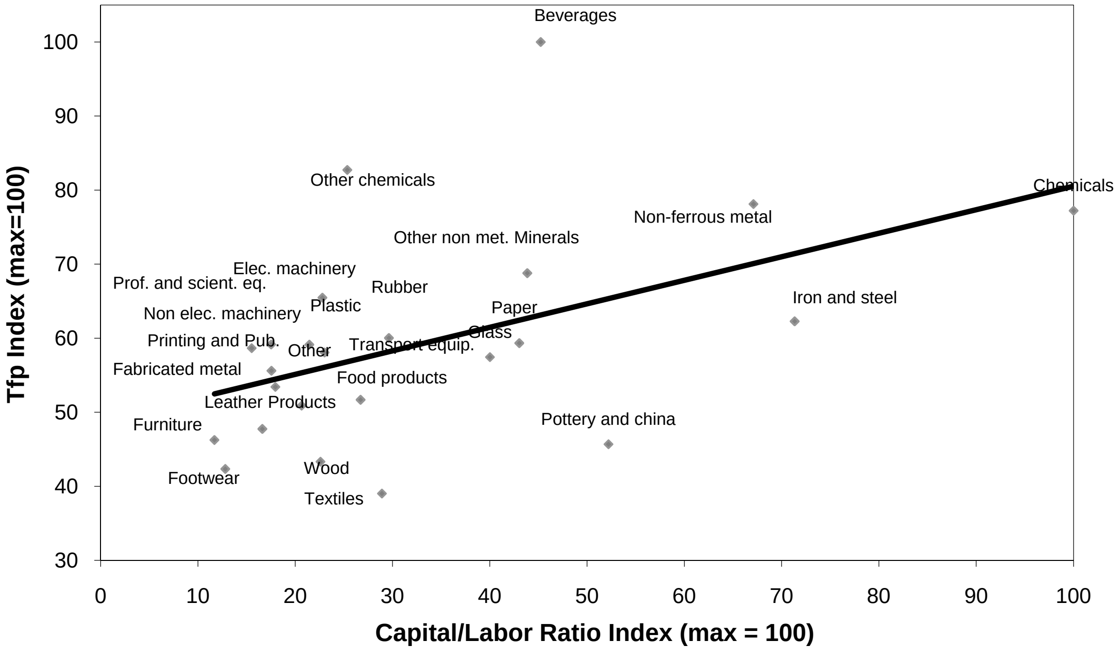
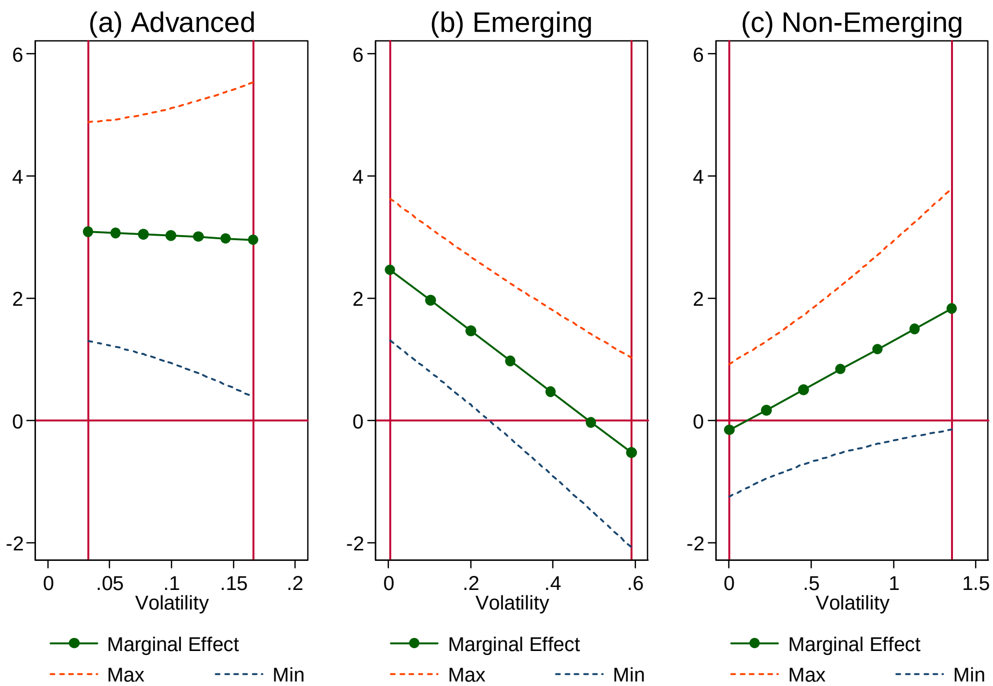


Figure 2. Marginal Impact of Relative TFP on Investment Shares



Note: This graph represents the response of investment shares to TFP changes under different volatility scenarios. This is constructed using information in Table 1 Column 3.

Table 1. Baseline Specification

Dependent Variable: Investment Ratio	(1)	(2)	(3)	(4)
	σ_{60}		σ_{60}	
	OLS	IV	OLS	IV
Tfp	0.297 [0.522]	0.0819 [0.565]		
Tfp*σ	-0.851 [0.835]	-0.158 [0.968]		
Tfp*Advanced			3.12*** [0.894]	3.19*** [0.968]
Tfp*σ*Advanced			-0.975 [6.48]	-0.536 [6.79]
Tfp*Emerging			2.49*** [0.592]	2.67*** [0.68]
Tfp*σ*Emerging			-5.11*** [1.44]	-5.81*** [1.6]
Tfp*Non-Emerging			-0.163 [0.553]	-0.286 [0.559]
Tfp*σ*non-Emerging			1.47 [0.971]	2.07* [1.12]
Observations	10099	8795	10099	8795
Number of Countries	65	65	65	65
Country Time Fixed Effects	yes	yes	yes	yes
Industry Time Fixed Effects	yes	yes	yes	yes

Notes: Standard errors corrected by industry-country clusters in brackets *** p<0.01, ** p<0.05, * p<0.1. All specifications include industry-time and country-time effects. IV estimators include the second lag of the TFP ratio as an instrument.

Table 2. Robustness 1: Alternative Definitions of Volatility

Dependent Variable: Investment Ratio	(1)	(2)	(3)	(4)
	σ_{24}		σ_f	
	OLS	IV	OLS	IV
Tfp*Advanced	3.04***	2.99***	3.33	4.45
	[0.716]	[0.744]	[2.11]	[3]
Tfp*σ*Advanced	-0.686	1.04	-2.25	-10.3
	[4.29]	[4.13]	[16.7]	[23.1]
Tfp*Emerging	2.27***	2.41***	2.6***	2.87***
	[0.566]	[0.648]	[0.624]	[0.729]
Tfp*σ*Emerging	-4.54***	-5.25***	-5.55***	-6.67***
	[1.3]	[1.47]	[1.69]	[1.9]
Tfp*Non-Emerging	-0.145	-0.259	-0.348	-0.533
	[0.578]	[0.571]	[0.558]	[0.576]
Tfp*σ*non-Emerging	1.48	2*	2.5*	3.5**
	[1.07]	[1.05]	[1.38]	[1.6]
Observations	9773	8473	10099	8795
Number of Countries	65	65	65	65
Country Time Fixed Effects	yes	yes	yes	yes
Industry Time Fixed Effects	yes	yes	yes	yes

Notes: standard errors corrected by industry-country clusters in brackets *** p<0.01, ** p<0.05, * p<0.1. All specifications include industry-time and country time effects. IV estimators include the second lag of the TFP ratio as an instrument.

Table 3. Robustness 2: Crises as a Measure of Volatility (Emerging Countries)

Dependent Variable: Investment Ratio	(1) Banking Crisis	(2) Sist. Banking	(3) Currency Crisis
Tfp	1.25**	0.788**	1.36***
	[0.509]	[0.401]	[0.466]
Tfp*σ	-0.753*	-0.594**	-0.97***
	[0.407]	[0.236]	[0.363]
Observations	4036	4036	4039
Number of Countries	22	22	22
Country Time Effects	yes	yes	yes
Industry Fixed Effects	yes	yes	yes

Notes: Standard errors corrected by industry-country clusters in brackets *** p<0.01, ** p<0.05, * p<0.1. All specifications include industry time and country time fixed effects.

Table 4. Robustness 3: – Alternative Measure of TFP

Dependent Variable: Investment Ratio	(1) OLS	(2) IV
	9.58***	16.6***
Tfp*Advanced	[2.52]	[4.03]
	-32.2	-94.7***
Tfp*σ*Advanced	[22.2]	[35.5]
	3.35***	4.42***
Tfp*Emerging	[1]	[1.56]
	-7.8***	-11.2***
Tfp*σ*Emerging	[2.99]	[4.59]
	1.76***	2.59***
Tfp*Non-Emerging	[0.869]	[1.08]
	-0.384	-2.6
Tfp*σ*non-Emerging	[3.18]	[3.89]
Observations	10539	9178
Number of Countries	65	65
Country Time Fixed Effects	yes	yes
Industry Time Fixed Effects	yes	yes

Notes: Standard errors corrected by industry-country clusters in brackets *** p<0.01, ** p<0.05, * p<0.1. All specifications include industry-time and country-time fixed effects. IV estimators include the second lag of the TFP ratio as an instrument.

Table 5. Robustness 4: Alternative Estimator (GMM)

Dependent Variable: Investment Ratio	(1) Advanced	(2) Emerging	(3) Non-Emerging
Investment Ratio (-1)	0.627***	0.329***	0.258***
	[0.0922]	[0.0971]	[0.0711]
Tfp	1.65**	1.83***	-0.128
	[0.65]	[0.672]	[0.336]
Tfp*σ	0.0735	-2.58*	0.529
	[1.89]	[1.42]	[0.557]
Observations	3182	3669	3225
Number of Countries	18	22	25
hansen	0.563	0.0936	0.605
ar(1)	<0.000	<0.001	<0.002
ar(2)	0.237	0.0579	0.856
Country Time Effects	yes	yes	yes
Industry Fixed Effects	yes	yes	yes

Notes: Standard errors are obtained through a two step variance estimator with the Windmeijer correction. *** p<0.01, ** p<0.05, * p<0.1. All specifications include industry and country time fixed effects.

Appendix 1. Sample of Countries

Country Classification		
Emerging	**Advanced**	**Non-Emerging**
Chile	Austria	Bangladesh
China (Macao SAR)	Belgium	Barbados
Colombia	Canada	Bolivia
Ecuador	Denmark	Bulgaria
Egypt	Finland	Cameroon
Hungary	France	Cyprus
India	Greece	Ethiopia
Indonesia	Ireland	Fiji
Israel	Italy	Iran, (Islamic Republic of)
Korea, Republic of	Japan	Jordan
Malaysia	Luxembourg	Kenya
Mexico	Netherlands	Kuwait
Pakistan	New Zealand	Malawi
Panama	Norway	Malta
Peru	Portugal	Morocco
Philippines	Spain	Myanmar
Poland	United Kingdom	Oman
Romania	United States of America	Senegal
Singapore		Sri Lanka
Slovenia		Swaziland
Turkey		TFYR of Macedonia
Uruguay		Trinidad and Tobago
Venezuela		Tunisia
		United Republic of Tanzania

Appendix 2. TFP Estimation

A crucial element for our analysis is the estimation of industry level TFP. Taking advantage of the data on gross fixed capital formation from the UNIDO dataset, we construct series of capital stocks for each industry in every country using a perpetual inventory approach, where initial capital K_0 is defined, following Caselli (2006), by equation (A1) (country, industry and time subscripts are omitted):

$$K_0 = \frac{I_0}{g + \delta} \quad \text{(A1)}$$

where I_o represents real gross fixed capital formation for a given industry for the first year when the data is available, g corresponds to the average growth rate of output in that industry for the entire sample period for which data is available (1963-2003), and δ is the depreciation rate of physical capital (that we set equal to 6 percent). Once we have a measure of the initial capital stock K_0, we estimate real capital stocks for subsequent years using the following motion equation:

$$K_t = (1 - \delta) * K_{t-1} + I_{t-1} \quad \text{(A2)}$$

This procedure is applied for the 26 industries in all countries where data are available. We proceed to compute two alternative measures of TFP that we subsequently use in estimations. The starting point of both measures is an industry-level production function, which we assume to be a standard Cobb-Douglas function with technological coefficients α (for physical capital) and β (for labor):

$$Y_{i,c,t} = A_{i,c,t} K_{i,c,t}{}^{\alpha} L_{i,c,t}{}^{\beta} \quad \text{(A3)}$$

where *Y*, *A*, *K* and *L* are: real value added, total factor productivity, real capital stock, and labor, respectively.[26] We are interested in finding a measure for *A* for every industry and country in every year. We construct *A* by log-linearizing (A3) and using suitable estimates of the coefficients α and β. First we use the standard values of 0.3 and 0.7 for capital and labor shares in the production function. Under the assumption of Cobb-Douglas production functions and

[26] We transform the series to constant prices using the US Consumer Price Index (base 2000) taken from the IMF International Financial Statistics (IFS). The list of countries, industries and time periods, as well as descriptive statistics of the data used in the study are reported in the Appendix.

perfect competition, these shares are the technological coefficients of the production function. Thus, *ltfp1*, the logarithm of TFP obtained using this methodology, is given by equation (A4):

$$ltfp1_{i,c,t} = y_{i,c,t} - 0.3k_{i,c,t} - 0.7l_{i,c,t} \qquad (5)$$

where subscripts indicate the natural logarithm of the corresponding variable. A drawback of this methodology is the restrictive assumption of fixed coefficients across industries. Thus, we construct an alternative measure that improves on this dimension. This proxy (*ltfp2*) is calculated in two steps: first, we use US aggregate data to estimate the rate of return for physical capital in the US. Then, assuming that this rate of return is the same for all industrial sectors in the country, we use it to compute industry-specific capital and labor coefficients for the 26 industrial sectors.

The procedure is as follows: first we use labor share α_L for the Unites States as estimated by Bernanke and Gurkaynak (2001) to infer the capital share α_K for that country. Assuming constant returns to scale for the technological process we have that the capital share α_K is equal to:

$$\alpha_K = 1 - \alpha_L \qquad (A5)$$

Under perfect competition and using a Cobb-Douglas production function, the following relationship holds at the economy-wide level:

$$\alpha_K = \frac{r * K}{VA} \qquad (A6)$$

where *K* is the capital stock, *VA* the value added for the US economy and *r* is the rate of return to physical capital. Thus:

$$r = \frac{\alpha_K * VA}{K} \qquad (A7)$$

We use (A5) and (A7) to infer a rate of return of capital *r* for the United Sates in a particular year (i.e., 1987). For this purpose, we use data from the National Bureau of Economic Research's Manufacturing Industry Productivity Database for *VA* and *K*. Once we have estimated *r,* we can compute α_{Ki}, i.e., the capital share *for each* industry, using data from the same base year, assuming that *r* is the same for the entire manufacturing sector:

$$\alpha_{Ki} = \frac{K_i}{VA_i} * r \qquad \text{(A8)}$$

Next, we assume that these capital shares are the same in other countries and constant over time. Thus, the TFP measure, *ltfp2*, corresponds to the growth accounting residual of the log-linearized version of (A3) that is obtained using α_{Ki} and the corresponding $\alpha_{Li} = 1 - \alpha_{Ki}$ as the capital and labor technological coefficients, respectively, for each industry in every country/year:

$$ltfp2_{i,c,t} = y_{i,c,t} - \alpha_{Ki} k_{i,c,t} - (1 - \alpha_{Ki}) l_{i,c,t} \qquad \text{(A9)}$$

This measure of TFP is very similar to the previous one, with the added benefit that the technological coefficients vary across industries. We use both measures to compute the relevant ratios used for the estimation of equation (9).

Appendix 3. Descriptive Statistics

Variable	Obs	Mean	Std Dev.	Min	Max
All					
Investment Share	13223	0.049	0.073	0.000	0.991
Tfp ratio	12695	0.051	0.024	0.004	0.560
Tfp Alternative ratio	12169	0.053	0.026	0.010	0.556
σ_{24}	11918	0.091	0.136	0.003	1.654
σ_{60}	12349	0.119	0.151	0.003	1.357
σ_f	12432	0.144	0.146	0.003	1.183
Advanced Economies					
Investment Share	3794	0.045	0.050	0.000	0.403
Tfp ratio	3782	0.045	0.009	0.031	0.127
Tfp Alternative ratio	3635	0.047	0.011	0.027	0.133
σ_{24}	3261	0.084	0.032	0.019	0.194
σ_{60}	3692	0.099	0.027	0.033	0.166
σ_f	3775	0.121	0.013	0.045	0.159
Emerging Economies					
Investment Share	4874	0.046	0.068	0.000	0.667
Tfp ratio	4740	0.047	0.018	0.004	0.515
Tfp Alternative ratio	4546	0.049	0.020	0.017	0.556
σ_{24}	4473	0.084	0.098	0.003	0.643
σ_{60}	4473	0.117	0.107	0.005	0.590
σ_f	4473	0.131	0.096	0.009	0.590
Non-emerging Economies					
Investment Share	4555	0.055	0.092	0.000	0.991
Tfp ratio	4173	0.060	0.034	0.004	0.560
Tfp Alternative ratio	3988	0.063	0.036	0.010	0.543
σ_{24}	4184	0.104	0.204	0.003	1.654
σ_{60}	4184	0.140	0.231	0.003	1.357
σ_f	4184	0.179	0.226	0.003	1.183

Note: The values that appear with a zero on the table appear that way because of an approximation to the nearest thousandth. No sector has a zero share of investment. The values are small, but actually positive.

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