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## Article

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# Balance sheet effects in currency crises: Evidence from Brazil<sup>☆</sup>

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## ABSTRACT

In third generation currency crises models, balance sheet losses from currency depreciations propagate the crises into the real sector of the economy. To test these models, we built a firm-level database that allowed us to measure currency mismatches around the 2002 Brazilian currency crisis. We found that between 2001 and 2003, firms with large currency mismatches just before the crisis reduced their investment rates 8.1 percentage points more than other publicly held firms. We also showed that the currency depreciation increased exporters revenue, but those with currency mismatches reduced investments 12.5 percentage points more than other exporters. These estimated reductions in investment are economically very significant, underscoring the importance of negative balance sheet effects in currency crises.

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## 1. Introduction

The international financial crises in the 1990s that struck many emerging countries inspired a group of models designed to explain currency crises based on firms' decisions. Called third generation currency crisis models, they focus on post-devaluation losses suffered by firms with unhedged foreign debt. In imperfect capital markets, these negative balance sheet effects tighten credit restrictions, leading to a reduction in investments that propels the currency crisis into the economy's real sector (Krugman, 1999; Aghion et al., 2001).<sup>1</sup>

<sup>☆</sup> This article should not be reported as representing the views of the Banco Central do Brasil. The views expressed in the papers are those of the author(s) and do not necessarily reflect those of the Banco Central do Brasil.

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<sup>1</sup> Hubbard (1998) reviews the literature on investment and credit market imperfections.

To evaluate those models, some studies have used firm-level information, estimating the impact on investment of balance sheet changes due to exchange rate movements. However, while in some of them firms that hold more dollar debt invest less in the wake of currency devaluation, other studies identify non-significant – or even positive – effects of the balance sheet losses on investment.<sup>2</sup>

As a rule, the results' ambiguity is partly because the use of foreign currency hedge instruments is only reported in the explanatory notes of financial statements. This data limitation means that empirical works often disregard hedge instruments and use dollar debt as a proxy for currency mismatches. Consequently, they overestimate currency mismatches and underestimate the impact of currency losses on firms' investments, a bias that should vary in different countries depending on firms' hedging vehicles.

In this article, we test the transmission mechanism for balance sheet losses using a database that allows us to measure the currency mismatches – defined as foreign currency debt net of foreign currency assets and derivatives – of publicly held Brazilian firms between 2000 and 2004. This period includes the Brazilian currency crisis of 2002, which resulted in a 53% depreciation of the *real* vis-à-vis the dollar. Having a currency mismatch measure, we adopt an empirical strategy that focuses on the drop in investment by firms with unhedged foreign currency debt resulting from currency depreciation.

If the balance sheet losses resulting from currency devaluation were the only significant event of 2002, the difference in investment (before and after the crisis of 2002) by firms with unhedged foreign debt just before the crisis would give us an estimate of the balance sheet effect. It is quite unlikely, however, that the balance sheet effect was the only important channel of the crisis of 2002. Currency crises almost always affect the economy's relative prices, impacting firms' investment propensity. Thus, the difference in investment by firms with currency mismatches reflects not only balance sheet effects, but also other consequences of the crisis that impact all firms, inclusive events not observable.

There is, however, a simple way to separate balance sheet effects from other effects. The difference in investment by firms without pre-crisis currency mismatches would seem to capture the full range of effects from the crisis, except for balance sheet effects. Therefore, the difference in investment changes by firms with and without currency mismatches provides estimation of the balance sheet effects.

Applying this difference-in-differences method to our data, we found that the effect of the 2002 depreciation on publicly held firms that reported balance sheet losses was that they reduced their investment rates more than firms that did not report losses: 8.1 percentage points in 2003 and 5.5 percentage points in 2004 in comparison to 2001 (the year prior to the crisis of 2002). Given that the average investment rate of all the firms was 8.1% in 2001, the significant economic impact of balance sheet effects is more than evident.<sup>3</sup>

As we elaborate in the text, the estimates for investment cuts incorporate firm characteristics to control any bias in selecting the firms with unhedged foreign debt (treatment group) and firms without currency mismatches (control group). These two groups were formed in such a way that balance sheet effects would apply only to the treatment group.

We may strengthen the reliability of the treatment and control groups by considering a subset of these two groups: export firms. The advantage of this alternative test is that currency depreciation may affect export firms through both the balance sheet channel and the competitiveness channel. Currency depreciation should not only imply financial losses for firms with unhedged foreign debt, but also competitiveness gains for export firms. In this case, if balance sheet effects are important, increases in investments by export firms should be less dramatic for those with unhedged foreign debt.

The results do in fact show very significant competitiveness and balance sheet effects following the Brazilian crisis of 2002. Between 2001 and 2003, export firms increased net revenue and investment 16.8% and 10.9 percentage points more than non-exporting firms, and the investment rates of exporters with currency mismatches just prior to the crisis fell 12.5 percentage points more than the rates of export firms without currency mismatches. These results from the Brazilian currency crisis of 2002 support that there is a sharp drop in aggregate investment during currency crises in economies where many firms have unhedged foreign debt.

The remainder of the article is organized as follows: the next section briefly describes some empirical evidence on balance sheet effects; Section 3 describes the database; Section 4 estimates the balance sheet effect of the Brazilian currency depreciation of 2002 on investment rates, Section 5 analyzes the robustness of the results; Section 6 estimates the balance sheet effect together with the competitiveness effect of the 2002 currency crisis; lastly, Section 6 concludes.

## 2. Existing evidence

The emerging market currency crises of the 1990s were characterized by dramatic drops in economic activity and collapsing financial systems. These crises fueled debate on the impact that currency depreciation had on economies' performances. Extensive theoretical writing ensued, showing that when currency mismatches are present, currency devaluations can be contractionary, reversing the expansionary effects of the conventional open economy models. However, these models do not provide conclusive results. For example, Céspedes et al. (2002) show that depreciations are contractionary

<sup>2</sup> For a review of literature that tests the balance sheet effects of currency depreciation, see Galindo et al. (2003a).

<sup>3</sup> Our differences-in-differences approach follows Abadie (2005).

only when there are simultaneously high levels of foreign debt and large imperfections in the international capital markets.

In fact, [Céspedes \(2004\)](#) and [Galindo et al. \(2003b\)](#), using macroeconomic data from a set of countries, found evidence that foreign debt reduces the expansionary effect of currency depreciations, and may even turn them contractionary in cases of high foreign debt. These results were not fully confirmed, however, by studies using firm-level data. Using a sample of firms from seven Latin American countries in the 1991–1999 period, [Bleakley and Cowan \(2002\)](#) found that firms with greater foreign currency debt invest more following periods of currency depreciation. On the other hand, [Aguiar \(2005\)](#) showed that after the Mexican crisis of 1994, the exporters' investment was constrained by weak balance sheets.

An initial attempt to reconcile these ambiguous results was made by articles that analyzed the importance of the balance sheet effects for six Latin American countries separately (Argentina, Brazil, Chile, Colombia, Mexico and Peru).<sup>4</sup> These articles followed the standard approach of [Bleakley and Cowan \(2002\)](#), but presented some innovations as the use of dynamic panel techniques (GMM) to incorporate the covariance structure in time and address possible endogeneity problems of the independent variables. The evidence from these studies is also inconclusive. While for Mexico, Argentina, Peru and Brazil the balance sheet effects were negative and significant, for Colombia and Chile the balance sheet losses provoked by currency depreciation did not significantly impact their firms' investments.<sup>5</sup>

The ambiguity continued. Other studies that attempt to test balance sheet effects sought more precise measures for currency mismatches that would incorporate firms' currency hedge positions. [Cowan et al. \(2005\)](#) studied the case of Chile and showed that, consistent with previous studies on Chile, firms with higher foreign currency debt did not invest less after periods of currency depreciation. However, when foreign debt was measured net of currency assets and derivatives, the balance sheet effects of currency depreciation became negative and significant. In a case study of Colombia, [Barajas et al. \(2017\)](#) found that for a given level of foreign currency debt, having foreign assets or natural hedge can reduce the sensitivity of firm-level investment to exchange-rate fluctuation. Moreover, they also found evidence of a balance sheet effect that transmits exchange rate fluctuations to investment asymmetrically, much stronger for depreciations than for appreciations.

In a different approach, [Serena and Souza \(2018\)](#) aggregate bond-level information at the firm-level to depict in detail the composition of liabilities in terms of currency, maturity and market of issuance of about 1000 firms based in 36 EMEs over the period 1998–2014. They found that, conditional on the amount of debt issued in foreign currency, an exchange rate depreciation can have a contractionary impact on a firm's investment spending.

In the aftermath of the Great Financial Crisis of 2008–2009, Emerging market corporate bond issuance denominated in US dollars surged. [Avdjiev et al. \(2014\)](#) have documented a rapid increase of external borrowing of non-financial corporates through offshore issuance of debt securities and [Caballero et al. \(2014\)](#) shown that external borrowing by these corporations is mostly in US dollars. Such developments translated into sharp rises in aggregate currency mismatches with weaker balance sheets of the EME corporate sector and led again to concerns about the potential impact of currency depreciation on the real economy ([Chui et al., 2018](#)). But unlike in earlier episodes, this time it was corporates, rather than governments, that put emerging market economy financial systems at risk.

Many studies (e.g. [Burger et al., 2015](#); [Chari et al., 2017](#); [Fratzscher et al., 2018](#)) provide evidence that the expansionary policies pursued by the advanced economies central banks have led investors to buy EME bonds in a search for yield, which encouraged EME borrowers to issue more foreign currency bonds, as advanced economy savers exhibit home currency bias ([Burger et al., 2018](#); [Maggiore et al., 2018](#); [Boermans and Vermeulen, 2016](#)), and so prefer bonds denominated in their own currency.

This article follows the line of [Cowan et al. \(2005\)](#) by incorporating currency hedge positions into our measure of currency mismatches and net exports in our regressions. However, our work differs from his and the other aforementioned articles in some key aspects. First, our database is the only one that combines a large depreciation with more precise information of currency mismatches by the firms. Moreover, the Brazilian currency depreciation of 2002 can largely be viewed as related to the presidential election campaign, where the frontrunner candidate Lula initially refused to declare a commitment to fiscal discipline and pro-market policies. This political-economy aspect isolates the currency depreciation from concurrent fundamental economic causes that may trigger currency depreciations in other contexts and gives the exchange rate depreciation a more experimental character than is typically the case. Therefore, we have a very powerful natural experiment to test the impact of balance sheet effects. Second, our econometric procedure allows us to limit the sample period to the time around 2002 currency crisis. Restricting the sample period to the years just before and after the crisis, we avoid the inclusion of periods with low exchange rate volatility that could bias the balance sheet effect result.<sup>6</sup> In addition, we emphasized building a control group of firms that were not subject to the balance sheet losses. As explained in the introduction, the control group allowed us to isolate the impact of balance sheet effects using only investment data

<sup>4</sup> See [Galindo et al. \(2003a\)](#).

<sup>5</sup> In the case of Brazil, we adopted the results described in [Bonomo et al. \(2003\)](#), which is a revised version of the article these authors published in the *Emerging Markets Review* 2003.

<sup>6</sup> [Bonomo et al. \(2003\)](#), for example, argue that the negative balance sheet effects in Brazil were limited to the floating exchange rate period (1999–2002). When they restricted the sample to the same period that [Bleakley and Cowan \(2002\)](#) used, which included only one year of floating exchange rate, the result is that firms with greater foreign currency debt invest more following periods of currency depreciation.

around the time of the crisis by comparing, for example, differences in investment by exporters with and without currency mismatches.

### 3. Data description

#### 3.1. Sample period

This study is built around the Brazilian currency crisis of 2002. In that year, the Brazilian exchange rate fell approximately 53% in relation to the dollar. The depreciation of the Brazilian currency began in April and reached its maximum in September of 2002, on the eve of presidential elections in which a leftist party was highly favored to win (which proved accurate). What, luckily, did not prove accurate were market expectations regarding the economic policy put in place by the new government. The new President Lula's economic policy kept the three basic pillars of his predecessor's: inflation targeting regime, floating exchange rate and high primary government surpluses.

Firms that had heavy unhedged foreign debt suffered enormous financial losses in the crisis. Moreover, the cost of foreign loans rose considerably and the rollover rate for foreign currency debt fell, indicating tighter credit restrictions.<sup>7</sup> These conditions offer a natural experiment for testing the balance sheet effects. In order to analyze this experiment we identify a treatment group formed of firms that reported large financial losses with the currency depreciation of 2002 and a control group formed of firms that did not report balance sheet changes.

After identifying the control and treatment groups, we tested the balance sheet effects using the “difference-in-differences” method, which compares the average difference in investment rates of firms in the control and treatment groups before and after the currency depreciation. Implementing our econometric strategy required, however, pre-crisis data, for which we used only the years 2000 and 2001 to avoid contamination from the currency crisis of January 1999, which culminated in flexibilization of Brazil's exchange rate regime. As post-crisis periods, we evaluated only the two years following the crisis (2003–2004). The year 2002 was not included in the sample because the currency depreciation began in April of 2002, which could affect the results if firms invested in the first quarter of the year. Fig. 1 traces Brazil's nominal exchange rate between 1997 and 2004, particularly the substantial depreciations in January 1999 and during the second semester of 2002.

#### 3.2. Sample construction and database

The Economática database served as the foundation for the sample selection.<sup>8</sup> From an initial sample of 477 Brazilian publicly held firms, we established an unbalanced panel of 274 firms. We excluded firms in the financial and insurance sectors; those that were not trading publicly in 2002; diversified holding firms with stakes in financial firms or without operational revenues; those whose balance sheet dates were not December; and those that did not have financial statements available for our sample period.

We used the firms' consolidated financial statements instead of the controlling firms' statements because many publicly held Brazilian firms are holding firms with no operational income or debt in foreign currency during the period analyzed.<sup>9</sup> Additionally, many of the firms analyzed, even those that are not holding firms, borrowed overseas or had foreign currency assets through controlled firms. Thus, by consolidating the data we are also analyzing firms that are not publicly held, but are directly or indirectly controlled by the firms in our sample.

To test the balance sheet effects, we measured firm performance by its gross investment rate, which is the sum of fixed asset variation plus depreciation divided by once lagged fixed assets.<sup>10</sup> So that this investment measure would most accurately reflect the balance sheet effect of currency depreciation, we made some adjustments to our sample. First, we excluded firms that reported negative net worth before the crisis of 2002. These 30 firms were probably in financial distress prior to the currency shock, which could distort their investment policies.<sup>11</sup>

We then researched news reports in the Economática database on each firm to identify changes in capital during the sample period that were not directly related to currency depreciation, such as mergers and acquisitions, the sale of stock holdings in subsidiaries and reassessments of fixed assets; these operations normally imply changes in fixed assets not

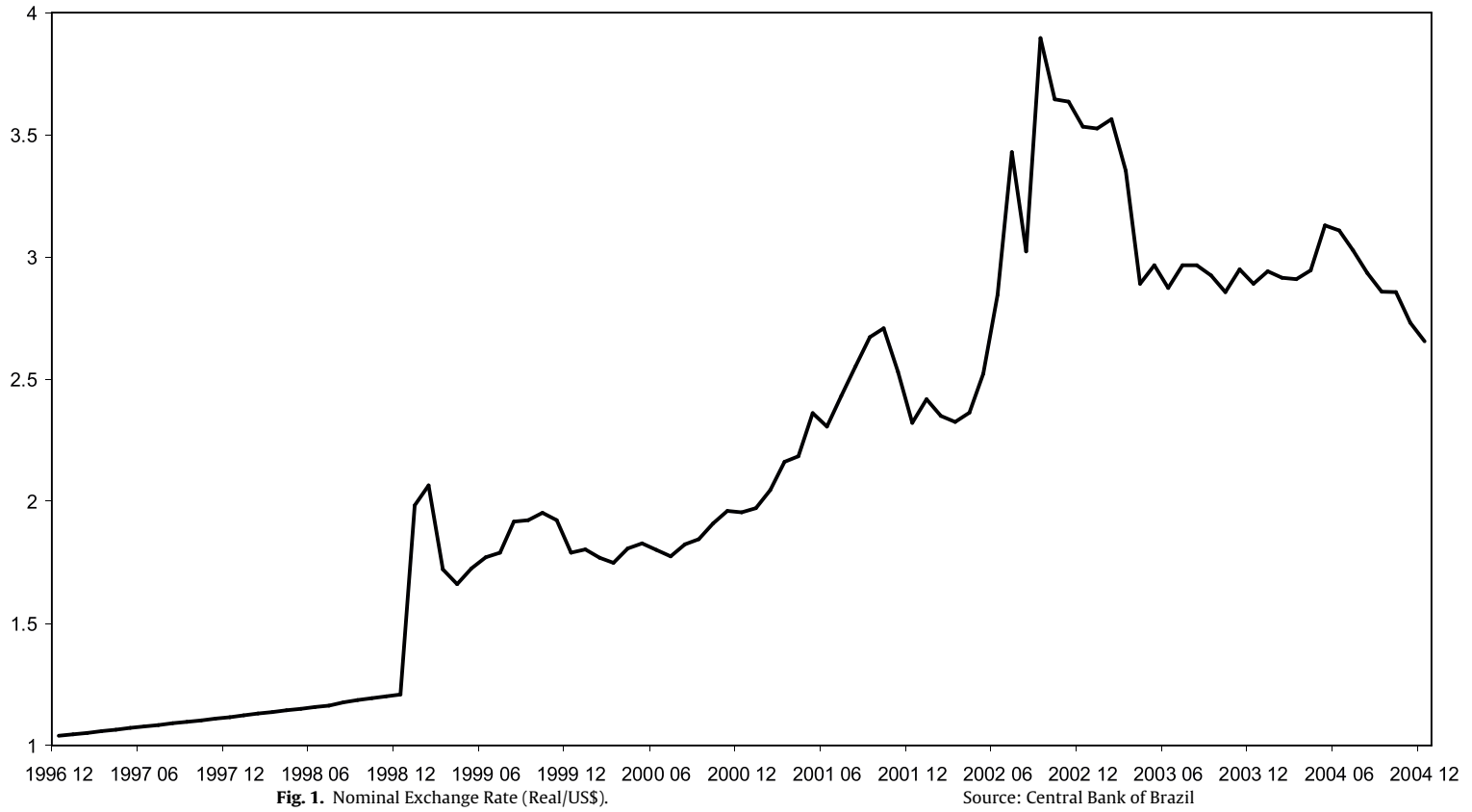
<sup>7</sup> . The Central Bank of Brazil's 2002 Annual Report shows that the rollover rate for notes and commercial papers fell from 83% in the second half of 2001 to 16% in the second half of 2002, while that of direct loans fell from 111% to 68% for the same comparison period. Although we do not have data on firms' borrowing costs, the Brazilian country risk, measured by the Emerging Markets Bond Index Plus (EMBI+Br), an index calculated by JP Morgan, shows that the premium on Brazil's portfolio of securities over US Treasury securities with the same terms reached a record high of 2.436 base points on September 27, 2002. As the cost of overseas borrowing for firms is positively correlated with the cost of the country's borrowing, the EMBI+Br suggests there was a huge increase in loan costs for firms in 2002.

<sup>8</sup> For information about Economática see [www.economatica.com](http://www.economatica.com).

<sup>9</sup> For example, on the balance sheets of the 274 controlling firms in the sample in 2001, 53 firms did not report operational revenue and 101 firms did not have foreign currency debt. Consolidating controlling firm data with that of their controlled firms, the number of sample firms without foreign currency debt fell from 101 to 57.

<sup>10</sup> We did not use capital expenditures to measure investment, as this would significantly reduce our sample size due to the small number of firms for which Economática has this information.

<sup>11</sup> In the appendix we show that the main results did not change qualitatively if we keep these 30 firms in the sample.



related to balance sheet effects. Unfortunately, we did not find standardized information on the values of capital changes attributed to these events. Where we found the total amount of the operations, we excluded the observations (firms-year) from the sample when the value exceeded 10% of a firm's assets, assessed at the beginning of the year in which the operation took place. This criterion prevented small transactions from eliminating material information about the firms' investments.<sup>12</sup> However, this criterion may not be used in cases where the value of the stock transactions or asset reassessment was not reported in the news. In these cases, we avoided distortions of investment rates by excluding the observations in which the absolute value of the firms' gross investment rates exceeded 40%.<sup>13</sup> In total, the analysis of news reports resulted in the exclusion of 54 observations.<sup>14</sup>

With the sample defined, we then obtained from the Economática database information on some financial variables to be used in our analysis: investment rate, total assets, total revenue, operational profit and domestic debt, including debentures.

In addition to these financial variables, we collected firm-level confidential import and export data from the government Foreign Trade Secretariat (SECEX).<sup>15</sup> These data are important to our study for two reasons. First, import and export data allow us to analyze the competitiveness effect of currency depreciation, and second, they can influence currency mismatches and investment decisions and are thus important variables in our econometric analysis. Both the export and import values were converted into domestic currency using the year's average exchange rate, and like the other variables described in this section, subsequently deflated by the Consumer Price Index (IPCA).

Lastly, we calculated the currency mismatch for each firm in our sample to identify which of them suffered significant balance sheet losses from the currency depreciation of 2002. We defined currency mismatch as debt linked to foreign currency net of foreign currency assets and derivatives. Data on foreign currency debt and assets were collected from the explanatory notes of the firms' consolidated annual balance sheets, which were obtained from the Securities and Exchange Commission of Brazil (CVM). Foreign currency debt was calculated by the sum of loans in foreign currency, commercial debts, supplier financing and foreign securities. Foreign currency assets were calculated as the sum of financial market investments in foreign currency (cash, government issues indexed to the dollar and overseas client credits).

Based on confidential information from the Central Bank of Brazil, Oliveira (2004) compile data with information on all foreign currency swap contracts between financial institutions and non-financial firms between 1999 and 2002 registered with the Clearing House for the Custody and Financial Settlement of Securities (CETIP). These contracts are very representative of the demand for foreign currency hedge in Brazil. In 2002, for example, they responded by 97% of the positions taken by Brazilian firms in foreign currency derivative markets in 2002. We use this database to build our measure of foreign currency derivatives and complement with other currency derivatives reported in balance sheet notes.

### 3.3. Sample statistics

The final sample contains an average of 218 publicly held firms in the sample period, with a maximum of 232 in 2001 and a minimum of 197 in 2004. The main reason for this reduction between 2001 and 2004 was not the currency crisis of 2002, but changes in the firms' ownership structure: all sample firms that closed their capital after 2002 reported positive net worth.<sup>16</sup> In appendix we show the number of sample firms each year and classifies them in one of the following seventeen sectors: Food and Beverages, Commerce, Civil Construction, Energy, Electro-electronics, Industrial Machinery, Mining, Non-metallic Minerals, Paper and Pulp, Oil and Gas, Chemical, Steel and Metallurgy, Telecommunications, Textiles, Transportation Services, Vehicles and parts, and others.

One essential condition for our strategy to test balance sheet effects was a representative sample of firms with foreign debt prior to the crisis. Table 1 show that 77.6% of our sample firms had debt in foreign currency in December of 2001, a percentage that changed little during the sample period. A more detailed analysis (not presented in the table) indicates that only 7.6% of the firms did not have foreign debt throughout the entire sample period. However, firms with foreign debt may manage exchange risks using hedge instruments designed to avoid losses with devaluation of the *real*. Table 2 shows that in December of 2001, 53.9% of the sample firms had foreign currency assets or derivatives: 38.8% had foreign currency derivatives while 33.2% had foreign assets. In addition to hedge instruments, foreign currency debts may be covered by future export revenue net of imports, which could circumvent the credit restrictions that could imply a reduction in investment.

In fact, Table 1 does show a significant number of exporters and importers: in December of 2001, 58.2% of the firms exported and 67.7% of the firms imported. As the exporters usually have some importing activity (but not necessarily vice-versa), it is not surprising that there are more importers than exporters in our sample. Moreover, the import and export

<sup>12</sup> We test the use of lower cutoff values, such as 5% and 1% of assets and the main results did not change qualitatively.

<sup>13</sup> The main results did not change qualitatively with the use of cutoff values for investment rates equal to 30% and 50% in absolute value.

<sup>14</sup> In the appendix we show that the main results did not change qualitatively if we disregard the news reports analysis and keep the 54 observations in the sample.

<sup>15</sup> To reconcile SECEX data and financial data, we identified the firms by their Corporate Taxpayer Identification Numbers (CNPJ). This allowed us to consider firms with different CNPJs separately, even if they are in the same group. Since we used consolidated data, we also obtained import and export figures for 334 firms that are subsidiaries or associate firms of controlling firms in our sample.

<sup>16</sup> The telecommunications sector accounted for much of the reduction in the number of sample firms. When the privatization of Telebrás ended in 1997, many of the privatized firms underwent corporate restructuring and were incorporated by the controlling firms.



**Table 1**  
Characteristics of Sample Firms.

Characteristic of firms / Year	2000	2001	2002	2003	2004	Mean
With foreign currency debt	77.7%	77.6%	78.1%	79.3%	77.7%	78.1%
With foreign currency assets and/or derivatives	47.3%	53.9%	61.8%	58.1%	59.4%	56.0%
With foreign currency assets	30.4%	33.2%	37.7%	41.0%	41.1%	36.5%
With foreign currency derivatives	28.1%	38.8%	46.9%	35.5%	35.0%	37.0%
With export revenues	59.8%	58.2%	58.3%	60.4%	57.9%	58.9%
With import expenditures	71.9%	67.7%	67.5%	64.5%	65.5%	67.5%

Note: This table presents the percentage of the number of firms in the sample with debt, assets and derivatives in foreign currency, export revenue and import expenditures each year.

**Table 2**  
Descriptive Statistics.

Variable / Year	2000	2001	2002	2003	2004	Mean	Median
Foreign currency debt / Total asset	14.1%	14.8%	17.2%	14.7%	11.9%	14.6%	10.8%
Foreign currency asset / Total asset	2.3%	3.1%	3.8%	3.7%	3.3%	3.2%	0.0%
Foreign currency derivatives / Total asset	2.1%	3.7%	7.6%	4.5%	3.0%	4.2%	0.0%
Currency mismatch / Total asset	9.8%	8.0%	5.8%	6.6%	5.6%	7.2%	2.6%
Exports / Total revenue	10.3%	10.4%	10.2%	11.3%	11.7%	10.8%	1.0%
Imports / Total revenue	3.7%	3.2%	3.2%	3.2%	3.5%	3.4%	0.4%
Operational profit / Total asset	7.1%	8.1%	8.6%	8.1%	10.7%	8.5%	8.5%
Sales growth rate	9.4%	6.0%	2.6%	3.6%	8.8%	5.9%	7.0%
Investment rate	10.7%	8.3%	3.3%	5.5%	9.4%	7.4%	3.7%
Total revenue (US\$ million)	1086	1.038	775	1.052	1.278	1.046	294
Total asset (US\$ million)	1.774	1.598	1.161	1.430	1.418	1.476	131
Total debt / Total asset	25.5%	26.8%	29.5%	27.8%	24.9%	26.9%	26.3%

Note: This table presents the descriptive statistics on the firms during the sample period. Foreign currency debt was calculated as the sum of all debts indexed to or denominated in foreign currency, whether borrowed domestically or overseas. Foreign currency assets were calculated as the sum of financial market investments in foreign currency, mainly cash, government issues indexed to the dollar and overseas client credits. Foreign currency derivatives include positions in swaps contracted domestically or overseas and positions in other foreign exchange derivatives such as dollar options, futures and forwards. Currency mismatches were measured by the total foreign currency debt net of foreign currency assets and derivatives. Exports and imports were measured respectively by the sum of the exports and imports of the controlling and controlled firms obtained from the SECEX (sum weighted by the respective stock holdings). Both exports and imports were converted into domestic currency using the average exchange rate of each year. Net exports are exports net of imports. The investment rate is defined as  $(K(t) - K(t-1) + \text{depreciation}) / K(t-1)$ , where the capital stock (K) is defined as fixed assets net of depreciation. Total debt was calculated by the sum of the value of loans and financing in foreign currency and in domestic currency, including debentures. Operational profit was taken before tax and interest. Sales growth rate is measured by the change in the logarithm of total revenue. Total revenue and total assets were converted into dollars using the exchange rates at the end of each year.

**Table 3**  
Distribution of the firms' currency mismatches.

Percentile	Currency Mismatch / Total Asset
1%	−8.6%
5%	−3.8%
10%	−0.8%
25%	0.0%
50%	3.2%
75%	12.2%
90%	25.0%
95%	34.7%
99%	48.3%

Note: This table presents the distribution of currency mismatching on total assets of the sample firms in the year 2001, just before the currency crisis of 2002. The currency mismatch is measured by foreign currency debts net of foreign currency assets and derivatives.

figures of many of these firms account for a very small percentage of their total revenue. However, in aggregate level, our sample firms account for 39.4% of total Brazil's exports and 26.5% of its imports in 2004 (figures not presented in the table).

Just before the crisis of 2002 (December of 2001), firms had foreign debt equal to 14.8% of their assets (Table 2). This amount would imply large balance sheet losses after 53% currency depreciation like the one in 2002 if the firms have not matched their foreign currency debt with income linked to the exchange rate. The second and third lines of Table 3 show that the losses resulting from foreign currency debt in 2002 were partially offset by gains from hedging. Foreign currency debt in 2001 was partially covered by foreign currency assets (3.1% of total assets) and derivatives (3.7% of total assets), reflecting an average currency mismatch equal to 8% of total assets.

In 2002, average foreign currency debt and derivatives as a percentage of total assets grew substantially. However, at least some of this growth was due to currency depreciation, which impacted the value in domestic currency of these variables. After the crisis, the currency mismatch fell to 6.5% of total assets in 2003 and 5.6% in 2004. For the entire sample period, the



median currency mismatch, equal to 2.6% of total assets, was far less than the 7.2% average, which indicates that some firms had considerable unhedged foreign debt. In fact, the median of foreign currency assets and derivatives equal to zero shows that over half the firms did not hedge their exposure in the sample period.

Table 2 also shows that exports also rose in the period, on average accounting for 10.8% of total revenue while imports accounted for 3.4%. Thus, the average percentage of total export revenue net of imports was 7.3%. The Brazilian 2002 currency crisis did not affect significantly the profitability of the firms. The operational profit was 8.1% of assets in 2001 and 2003. On the other hand, sales and investment had a big decline. The sales growth rate dropped from 6% in 2001 to 2.6% in 2002 and the gross investment rate went from 8.3% in 2001 to 3.3% in 2002. After the crisis, both sales and investment started gradually to recover.

In terms of firm size (total assets and total operational revenue), the sample is highly varied because there were few large firms. While the median firm had total assets of 131 million dollars and revenue of 294 million, average total assets and average total revenue were equal to US\$ 1.5 billion and US\$ 1.0 billion, respectively. In terms of financial leverage measured by the percentage of total debt over total assets, the sample was not so disparate, with an average and median of 26.9 and 26.3%, respectively.

#### 4. Balance sheet effects

In the previous section, we provided evidence of large currency mismatches just before the currency crisis of 2002. These currency mismatches lead to severe balance sheet losses in the event of currency devaluation. These losses could induce credit constraints that in turn force firms to abandon investment projects.

In this section, we identify which firms presented foreign currency mismatches prior to the crisis of 2002 and test whether these firms (our treatment group) reduced their investments more than firms that did not report post-crisis balance sheet changes because they did not have currency mismatches (our control group).

##### 4.1. Treatment and control groups

Table 3 shows that, in fact, a large percentage of firms had large currency mismatches in December of 2001. For example, 25% of the firms had currency mismatches exceeding 12% of assets, and 10% of the firms had currency mismatches exceeding 25% of their assets. On the other hand, some firms had null or negative currency mismatches. Statistics not given in the tables identify 33 firms (14.2% of the total) with positions in currency assets or derivatives exceeding their foreign currency debt, and another 53 firms (22.8%) without currency mismatches in 2001, because they were either perfectly matched or reported no foreign currency positions on their balance sheets. Thus our sample contains a considerable number of firms that reported heavy losses from the crisis of 2002 and a large number that did not report losses.

To estimate the balance sheet effects of currency depreciation on firms' investment, we would ideally compare investment rates by firms that reported losses with their investment figures if there was no crisis (counterfactual). Unfortunately, there is no information on how much these firms would have invested if the crisis had not occurred. To address this problem, we compared the investment rate changes (before and after the crisis) of firms that reported losses from the crisis due to currency mismatches (treatment group) and firms that reported no crisis-related balance sheet changes (control group). The control group's average investment change thus gives us a way to replicate the counterfactual. To ensure that this counterfactual is accurate, we must then monitor possible selection differences between firms with and without currency mismatches.

Our treatment group has 102 firms while the control group has 130. The group of firms with mismatches includes all the firms that in 2001 had currency mismatches exceeding 5.3% of their assets. This cutoff value was chosen in such a way that the control group firms had an average currency mismatch over assets equal to zero and, in turn, no post-crisis balance sheet changes related to currency mismatches.

The first line of Table 4 shows there was no statistically significant difference in averages in the two groups' investment rates just before the currency crisis of 2002: the firms with mismatches invested an average of 7.6%, compared to the 8.9% of firms without mismatches. The average currency mismatch of the firms with mismatches was 18.4% of assets in 2001, a level that results in average losses of nearly 10% of assets after a 53% currency shock like the one in 2002.

The mismatched firms had a larger percentage of revenue from exports, 12.6% as compared to the 8.7% of firms without mismatches, but the difference in averages is not statistically significant ( $p$ -value of 0.111). The average difference in import figures between the groups was only 0.3% of revenue in favor of firms with mismatches. The groups presented no significant differences in operational profit and sales growth rates. In terms of size, the firms in the treatment group (with mismatches) were considerably larger than the firms in the control group. On average, the logarithms of the net revenue and assets of mismatched firms were equal to 13.6 and 14.1 as compared to the matched firms' 12.7 and 13.2. The mismatched firms were also significantly more leveraged, with debt of 36.3% of assets as compared to 19.4% of the matched firms. Foreign currency debt largely accounted for this leverage difference, as both groups reported average domestic indebtedness of around 12% of assets.

In summary, the results in Table 4 show that the groups of mismatched firms differed significantly from firms without mismatches, not only in terms of currency mismatches, but also in terms of size and leverage.

**Table 4**  
Summary of financial characteristics of firms with and without currency mismatches in 2001.

Groups of Firms Variables	Mismatched (N = 102)	Matched (N = 130)	Mean Difference ( <i>p</i> -value of <i>t</i> -test)		
	Mean	Median	Mean	Median	
Investment rate	7.6%	2.9%	8.9%	6.0%	−1.3% (0.589)
Currency mismatch / Total asset	18.4%	15.0%	0.0%	0.0%	18.4%*** (0.000)
Exports / Total revenue	12.6%	3.9%	8.7%	0.0%	3.8% (0.111)
Imports / Total revenue	3.4%	1.0%	3.1%	0.1%	0.3% (0.742)
Operational profit / Total asset	8.4%	8.4%	7.9%	8.2%	0.4% (0.712)
Sales growth rate	4.8%	4.5%	7.0%	4.4%	2.2% (0.534)
Log total revenue	13.6	13.9	12.7	12.7	0.9*** (0.000)
Log total assets	14.1	14.2	13.2	13.0	0.9*** (0.000)
Total debt / Total asset	36.3%	35.6%	19.4%	16.3%	17.0%*** (0.000)
Domestic debt / Total asset	12.3%	11.3%	11.8%	6.9%	0.5% (0.753)

Note: Selected summary statistics for firms with and without mismatches in 2001, just before the crisis of 2002. The investment rate is defined as  $(K(t) - K(t-1) + \text{depreciation}) / K(t-1)$ , where the capital stock (*K*) is defined as fixed assets net of depreciation. The currency mismatch is defined as foreign currency debt net of foreign currency assets and derivatives. The firms classified as having mismatches are those with currency mismatches exceeding 5.3% of their assets in 2001. We chose this cutoff value for the mismatched group so that the control group would have an average currency mismatch over assets equal to zero. Exports and imports were converted into domestic currency using the average exchange rate for each year. Net exports are exports net of imports. Operational profits were calculated before tax and interest. Sales growth rate is measured by the change in the logarithm of total revenue. Total debt was calculated by the sum of the value of financing and loans in foreign currency and in domestic currency, including debentures. The far right column shows the differences in means and the *p*-values for tests of equality of means with different variances between the firms with and without mismatches. The coefficients significant to 10, 5 and 1% are indicated by \*, \*\* and \*\*\*, respectively.

## 4.2. Methodology and results

In order to test whether the currency crisis caused firms with currency mismatches to reduce their investments more than firms without currency mismatches, we conducted two sets of tests. The first was based on the differences-in-differences method and the second on propensity score matching. These methods of estimation are used in studies designed to evaluate the effectiveness of a specific exogenous intervention policy, estimating the policy's average effect (treatment) on the individuals affected (treated) by the policy. In our study, the treated firms are those that had large currency mismatches in the period immediately prior to the currency depreciation of 2002, that is to say those that were (negatively) impacted by the currency depreciation. The treatment effect is the impact on investment of losses resulting from the currency depreciation.

### 4.2.1. Differences-in-differences

The differences-in-differences approach estimates the balance sheet effect of the currency crisis on investment by the difference in average investment rate changes (before and after the crisis of 2002) of two groups of firms. One group had crisis-related balance sheet losses because they had unhedged foreign currency debts (treatment group), and the other group reported no losses (control group).

The idea of the differences-in-differences estimator is quite simple. If the balance sheet losses resulting from currency depreciation were the only significant event of the year 2002 that impacted investment, we could estimate this impact simply by the changes in investment rates (before and after the crisis) of firms with currency mismatches. However, since it is highly unlikely that the balance sheet effect was the only significant event in 2002, we deduced the control group's investment difference from the treatment group's investment difference. Since the control group's balance sheets were not affected by the currency depreciation, this difference in differences must exclude other events that could have influenced investment in the period for all firms.

The differences-in-differences estimator therefore should isolate the impact of balance sheet effects on investment, unless there was selection bias in forming the two groups. Selection bias may suggest, for example, distinct trends in the two groups' investment trajectories, independent of balance sheet effects. In the absence of due control, these pre-existing trends might lead to a distorted estimate of the balance sheet effect.

However, not all selection bias creates problems in the differences-in-differences method. Biases arising from variables that are constant over time (observed or not) are absorbed in the fixed effects of the differences-in-differences model. Examples of these variables are the industries, geographical locations and nationality of the firms. Relevant bias then is associated with selection variables that vary over time. The traditional way of handling pre-existing trends is to obtain the differences-in-differences estimator based on a regression model, in which specific variables are introduced linearly to monitor the trends of the treatment and control groups. Following [Abadie \(2005\)](#), we adopted this econometric specification:

$$Y(i,t) = \mu + X(i) \cdot \pi(t) + \tau \cdot D(i,1) + \delta \cdot t + \alpha \cdot D(i,t) + \varepsilon(i,t), \quad (1)$$

where  $Y(i,t)$  is the investment rate of firm *i* in period *t*.

In Eq. (1), the firms are observed in a pre-treatment period ( $t = 0$ ) and in a post-treatment period ( $t = 1$ ).  $D(i,t) = 1$  is an indicator variable that takes value one if firm *i* is part of the treatment group (firms with currency mismatches just before the crisis) and the period is post-treatment ( $t = 1$ ). Since the firms are only exposed to losses in the period  $t = 1$ ,  $D(i,0) = 0$  for all of *i*,  $D(i,1) = 1$  for the treated firms and  $D(i,1) = 0$  for those not treated. While the variable  $D(i,1)$  takes into

consideration differences in the treatment and control groups that are constant over time when measuring the average investment rates, variable  $D(i,t)$  captures the impact of balance sheet effects on this difference. The coefficient  $\alpha$  is therefore the differences-in-differences estimator.<sup>17</sup>

In addition to the variables that recover the differences-in-differences estimator, Eq. (1) contains a trend component common to all firms,  $t$ ; a random residual,  $\varepsilon(i,t)$ ; and a vector  $X(i)$  of the firms' characteristics, that controls possible differences in investment trajectories of the treatment and control groups. For this, the firms' characteristics should be correlated with investment and capture differences in the two groups.

As selection variables, we included exports and imports, both normalized by total revenue, operational profit over total assets, logarithm of total assets, sales growth rate, financial leverage and investment rate. All these variables are measured in the pre-crisis period and potentially determine hedge and investment decisions.

Export firms specifically should be less inclined to hedge, as their revenue's response to currency depreciation at least partially offsets any balance sheet losses; in contrast, importers are more inclined to hedge. While larger and more profitable firms may be less subject to credit restrictions and thus less inclined to hedge, firms with higher sales growth rate should have greater interest in hedging, because they tend to have more investment opportunities (Fazzari et al., 1988). Likewise, the relationship between financial leverage, measured by the percentage of total debt over total assets, and hedge decisions can be ambiguous. Firms with greater financial risk may want to hedge in order to minimize cash flow volatility and avoid paying predicted bankruptcy costs (Smith and Stulz, 1985). However, if shareholders see their shares as options in firm value, may be optimal to leveraged firms to speculate (Ljungqvist, 1994). Lastly, including the investment rate of the base period affords a dynamic to the investment, which can be seen when there are adjustment costs (Laeven, 2001).

In our sample, the firms are identified in each period  $t$ . We can therefore differentiate Eq. (1) with respect to  $t$ , obtaining the following econometric specification to estimate the balance sheet effects of the 2002 currency depreciation on investment. One advantage in differentiating Eq. (1) is that it clarifies elimination of non-observable variables that are constant over time.

$$\begin{aligned} InvestmentRate_{i,2003} - InvestmentRate_{i,2001} = & \delta + \alpha I(Mismatched)_{i,2001} \\ & + \Pi_1 InvestmentRate_{i,2001} + \Pi_2 (Export/Revenue)_{i,2001} + \\ & \Pi_3 (Import/Revenue)_{i,2001} + \Pi_4 (OperacionalProfit/Assets)_{i,2001} + \\ & \Pi_5 SalesGrowthRate_{i,2001} + \Pi_6 LogAsset_{i,2001} + \Pi_7 (Debt/Assets)_{i,2001} + \eta_{it} \end{aligned} \quad (2)$$

In Eq. (2), the dependent variable captures the adjustment of the gross investment rate before and after the 2002 currency crisis. The year 2001 is the base period (pre-crisis). As we explained in the preceding section, the year 2002 was excluded from the sample because, among other reasons, the currency depreciation began in April of 2002, which could affect our results if the firms had made investments in the first quarter of the year. We therefore analyzed the average balance sheet effects on the firms' investment rates in the year 2003. Variable  $I(Mismatched)$  is an indicator variable that assumes the value one for firms in the group with large currency mismatches in 2001 and zero in the opposite case.

If balance sheet losses resulting from currency depreciations raised loan costs, we should observe a relative reduction in investments by firms with currency mismatches as compared with firms protected from currency risk. In this case, the estimated coefficient  $\alpha$  should be negative. In the opposite case,  $\alpha$  should be statistically equal to zero. In these tests, we used clusters at firm level to estimate robust standard errors to serial correlation and heteroscedasticity.<sup>18</sup>

Column (A) of Table 5 presents the results of the estimation of a simplified version of our differences-in-differences model, without the variables that controls selection biases. In this specification, between 2001 and 2003 firms with currency mismatches invested 7.6 percentage points less than firms that did not report foreign currency losses related to the crisis of 2002. Introducing the variables that control selection biases, Column (B), the drop in investment by the firms with mismatches is even sharper and more significant. The firms with currency mismatches reduced their investment rates 8.2 percentage points more with a  $p$ -value of 0.004. Thus there is favorable evidence that the balance sheet effects of currency depreciations led to substantially reduced investment. The economic significance of these balance sheet effects is considerable given that the average investment rate of all firms was 8.1% in 2001.<sup>19</sup>

Among the vector of characteristics of the firms, only two variables significantly impacted the change in investment rates around the 2002 currency crisis: exports over total revenues and the investment rate in the base period. The percentage of exports in total revenues positively affected the firms' investment rates following the currency crisis, indicating competitiveness gains. The negative coefficient of the investment rate in the base period may signal the presence of adjustment costs and lumpy capital formation.

<sup>17</sup> For a more detailed discussion of the differences-in-differences models and possible extensions, see Meyer (1995).

<sup>18</sup> Bertrand et al. (2004) show that allowing an arbitrary covariance structure between the periods of time reduces problems of serial correlation in studies that apply the differences-in-differences method with over 50 observations in the cross section.

<sup>19</sup> We re-estimate our differences-in-differences model including the 30 firms that we dropped from the sample because they were probably in financial distress before the crisis of 2002 and the 54 observations that we had identified changes in capital that were not directly related to currency depreciation. As shown in Table A2 in Appendix, the coefficient of the variable  $I(Mismatched)$  is still negative and significant in both regressions.

**Table 5**  
Balance Sheet Effects on Investment: Differences-in-differences.

	$\Delta(\text{Investment rate})$				
	(A)	(B)	(C)	(D)	(E)
I(Mismatched)	−0.076* (0.043)	−0.082*** (0.028)	−0.056* (0.031)		
Currency Mismatch / Total Assets				−0.408*** (0.123)	−0.302*** (0.110)
Investment rate		−0.863*** (0.070)	−0.823*** (0.127)	−0.865*** (0.068)	−0.820*** (0.127)
Exports / Total revenue		0.179** (0.097)	−0.007 (0.072)	0.175** (0.077)	−0.019 (0.072)
Imports / Total revenue		−0.022 (0.121)	−0.023 (0.112)	0.031 (0.117)	0.032 (0.114)
Operational profit / Total asset		0.102 (0.196)	0.023 (0.339)	0.097 (0.198)	0.027 (0.343)
$\Delta(\text{Log Sales})$		−0.008 (0.038)	−0.092 (0.108)	−0.011 (0.037)	−0.098 (0.109)
Log total assets		−0.003 (0.008)	−0.014* (0.007)	−0.004 (0.007)	−0.016** (0.007)
Total debt / Total asset		−0.021 (0.070)	0.047 (0.076)	0.031 (0.077)	0.092 (0.085)
Constant	−0.011 (0.749)	0.097 (0.101)	0.282*** (0.108)	0.101 (0.101)	0.292** (0.107)
Obs.	217	217	197	217	197
R <sup>2</sup>	0.01	0.71	0.68	0.71	0.68

Note: This table contains the results of the least squares estimation of variants of Eq. (2) in the text. The dependent variable is the change in gross investment rate, measured as  $(K(t) - K(t-1) + \text{depreciation}) / K(t-1)$ , in which the capital stock ( $K$ ) is defined as fixed assets net of depreciation. The year 2001 is used as a base (pre-crisis). The year 2003 is used for the post-crisis data in Columns (A), (B), (D) and the year 2004 in Column (C) and (E). I(Mismatched) is an indicator variable that takes the value one for firms with currency mismatches exceeding 5.3% of their assets in 2001 and zero in the opposite case. Currency mismatch is defined as foreign currency debt net of foreign exchange assets and derivatives. The other control variables are fixed in the base year. Exports and imports were converted into domestic currency using the average exchange rate for each year. Total debt was calculated by the sum of the value of loans and financing in foreign currency and domestic currency, including debentures. Operational profit was calculated before tax and interest. Sales growth rate is measured by the change in the logarithm of total revenue. Sales growth rate is measured by the change in the logarithm of total revenue. Log of total assets is the logarithm of total assets. We used clusters at the firm level to estimate standard errors and to correct possible errors of serial correlation and heteroscedasticity. We reported the robust standard errors in parentheses. (\*\*, \*, \*) indicate significance at the 1%, 5% and 10% level.

To capture the endurance of the impact of balance sheet losses on investment rates, we re-estimated our model replacing the year 2003 with 2004 as the post-crisis period. Column (C) shows that the negative balance sheet effects did not dissipate in the second year after the currency shock. Relative to the matched firms, the firms with currency mismatches reduced their investments between 2001 and 2004 by 5.6 percentage points more ( $p$ -value 0.075). Once again, the results indicate the relevance of balance sheet effects.

In order to get a measure of elasticity, we substitute in the last two columns the treatment dummy, I(Mismatched), with a continuous variable of currency mismatch over total assets. We use the year 2003 as the post-crisis period in column (D) and the year 2004 in column (E). The results show that an increase in currency mismatch over assets by 10% was followed, ceteris paribus, by a reduction in investment rate of 4 p.p. in 2003 and 3 p.p. in 2004 (both in comparison to 2001 levels). The coefficients are significant at 1% level.

#### 4.2.2. Propensity score matching

As previously noted, one fundamental condition for testing the impact of balance sheet effects from currency depreciations is to control possible differences between treatment and control group firms to ensure that investment changes are due only to the balance sheet effects. Ideally the control group is random and identical to the treatment group except for the currency mismatch factor. However, building such a control group may not be possible for at least two reasons: first, finding firms with these characteristics is not likely; second, if they do exist, they would not be found through a random experiment given that the level of currency mismatches over assets is decided by firms.

In the differences-in-differences method, possible biases in selecting the treatment and control groups are controlled by introducing a vector of characteristics of the firms ( $X$ ). One cause for concern in this approach, however, is the linear specification assumption for vector  $X$ . In contrast, propensity score matching is a nonparametric method that also addresses the difficulties of building a random control group. The results are based on the conditional independence assumption. Applied to our study, this assumption says that depending on the set of selection variables included in the model (which we will continue to call  $X$ ), the expected investment rate of control group firms should equal the expected investment rate of treatment group firms if the crisis had not occurred. The challenge in matching is to find a set of  $X$  variables that will satisfy the conditional independence assumption. In practical terms, however, the larger the number of variables included in the model, the more difficult it is to find control group firms similar to the treatment group firms, and moreover, the greater the problem, which could limit the use of the matching method. One alternative for managing these problems is to use a

function of the set of selection variables. Rosembaum and Rubin (1983, 1984) proved that, without loss of generality, we might substitute the  $X$  vector with the probability that, given  $X$ , the firm will be in the group with mismatches. This result motivates the propensity score matching: to find for each firm with currency mismatch a firm without currency mismatch with the closest probability of being in the group of mismatched firms, given vector  $X$ .

The first step is to run a PROBIT model to find the probability the firms will be in the group with mismatches. For this method of building the sample of counterfactual firms to be valid, a second assumption is needed: every firm with currency mismatch (treatment group) has a counterpart in the group of firms without currency mismatching (control group), and any firm is a possible participant.<sup>20</sup> In order to increase the chances of this assumption being satisfied, we restricted our sample to firms with and without mismatch whose propensity scores (i.e. their probability of being in the mismatched group, obtained in the PROBIT model) were in the common support of the joint distribution.

So  $T$  is the set of firms with unhedged foreign currency debts with a propensity score in the common support. The estimator of the average effect of the treatment on treated firms (i.e., the balance sheet effect of currency depreciation) is calculated by the following equation:

$$\sum_{i \in T} [InvestmentRate_{it} - InvestmentRate_{jt}] \frac{1}{N_T} \quad (3)$$

where, among the matched firms,  $j$  is the firm whose propensity score is closest to the mismatched firm  $i$  in the period  $t$ .<sup>21</sup>

With the exception of the investment rate, which is our variable of interest, we chose as selection variables the same ones used in the differences-in-differences model. Additionally, we included indicator variables for each of the seventeen sectors identified in Table 1.<sup>22</sup> The sectors may be important in determining the firms' currency mismatches. For example, firms that did not export but whose business involves tradeable goods could also benefit from the change in relative prices following the currency crisis. As such they could choose to assume greater currency risk than other firms.

Table 6 presents the results for each year of our sample. Panel A shows the results of the PROBIT. Size and financial leverage are important selection factors. The coefficients of these variables were positive and significant in all the years analyzed. These results suggest that large and more leveraged firms have a greater probability of having large currency mismatches. The coefficients of the other variables had the expected signs, but did not significantly affect the probability of the firms being in the group with mismatches.

Panel B of Table 6 shows that matching the treatment group with the control group brings a significantly lower average investment rate in the two years following the crisis of 2002 among the firms with currency mismatches, as compared to the firms without currency mismatches. More precisely, while the difference in the investment rate of both groups was not significant in 2001 (only 0.5 percentage points), the investment rate of the group with currency mismatches was 10.1 percentage points in 2003 and 6 percentage points in 2004 less than the group without mismatches.

In summary, the results found in this subsection corroborate the results obtained by using the differences-in-differences estimators: the balance sheet losses associated with the currency depreciation of 2002 negatively affected firms' investment.<sup>23</sup>

## 5. Robustness checks

The results described in the previous subsections suggest that currency depreciation of 2002 caused firms with large currency mismatches to reduce their post-crisis investment more than firms that did not report losses. We attribute this reduction to balance sheet effects. However, our results could have occurred due to other factors not related to the post-crisis balance sheet effects.

One key question in this literature is how to distinguish credit constraint firms from highly currency mismatched ones. If the firms in the treatment group were more credit constrained than the firms in the control group, they would have to reduce relatively more their investment in a currency crisis independently of the balance sheet effects, because credit dries up during crisis. To address this possibility, we included in our regressions the variable Total debt over Total Assets as a proxy for credit constraint.

To be more confident that our main results are not being explained by leverage effects we apply two different tests. First, we included in our difference-in-difference model an indicator variable  $I(\text{Mismatched} * \text{Leveraged})$  that assumes the value one only for the subset of 50% more leveraged firms in the group of mismatches ones in 2001. The results described in Column (A) of Table 7 show that the coefficient  $-0.02$  was not statistically significant, which indicate that the adjustment in investment rates after the crisis were caused by the currency mismatch and not by leverage.

<sup>20</sup> In formal terms, this assumption corresponds to  $0 < \text{Prob}\{I(\text{Mismatched})=1|X_{it}\} < 1$ , with  $X_{it}$  being the selection variables included in the model.

<sup>21</sup> This estimator is known in the literature as an average treatment on the treated (ATT). For a more detailed description of the matching method and use of a propensity score, see Blundell and Dias (2002).

<sup>22</sup> In the differences-in-differences model, these variables were incorporated into the fixed effects.

<sup>23</sup> We also tested the inclusion as selection variables the asset tangibility, defined as the proportion of long-term assets, and two binary variables indicating whether the firms were, respectively, multinationals or with shares listed overseas through American Depository Receipts. Additionally, we re-estimated the model excluding the sector activity variables. In all these alternatives, the negative balance sheet effects remained statistically significant at 5% (results not described in the tables).



**Table 6**  
Balance Sheet Effects on Investment: Propensity Score Matching.

Panel A: PROBIT				
Variables / Year	2000	2001	2003	2004
Exports / Total revenue	0.44 (0.527)	0.25 (0.714)	0.20 (0.761)	0.91 (0.208)
Imports / Total revenue	-0.33 (0.821)	-0.91 (0.524)	-1.48 (0.287)	-1.43 (0.300)
Operational profit / Total asset	-1.83 (0.259)	-0.53 (0.663)	-0.45 (0.686)	0.04 (0.973)
Log total assets	0.22*** (0.006)	0.12* (0.084)	0.13* (0.070)	0.19*** (0.015)
Total debt / Total asset	4.55*** (0.000)	3.15*** (0.000)	2.77*** (0.000)	2.50*** (0.000)
Constant	-4.36*** (0.000)	-2.96*** (0.002)	-2.84*** (0.003)	2.95*** (0.000)
Sector Dummies	Yes	Yes	Yes	Yes
Obs.	218	232	217	196
Pseudo-R <sup>2</sup>	0.34	0.24	0.20	0.19
Chi <sup>2</sup> (p-value)	0.000	0.000	0.000	0.000
Panel B: Propensity Score Matching				
	2000	2001	2003	2004
Matchings	110	97	86	82
Investment rate (Mismatched)	0.102	0.072	0.0146	0.058
Investment rate (Matched)	0.108	0.077	0.116	0.119
Investment rate Difference	-0.006	-0.005	-0.101***	-0.060**
Confidential Interval (1%)	(-0.164;0.127)	(-0.162;0.072)	(-0.256;-0.022)	(-0.264;0.005)
Confidential Interval (5%)	(-0.123;0.092)	(-0.137;0.051)	(-0.230;-0.050)	(-0.354;-0.013)
Confidential Interval (10%)	(-0.090;0.073)	(-0.094;0.040)	(-0.245;-0.064)	(-0.246;-0.022)

Note: Panel A presents the results of a PROBIT regression to calculate the probability that each firm in our sample would be in the group of firms with mismatches. Currency mismatch is defined as foreign currency debt net of foreign exchange assets and derivatives. The firms with mismatches are those with currency mismatches exceeding 5.3% of their assets in 2001. We chose this cutoff value for firms to be included in the group with mismatches so that the group without mismatches would have an average level of currency mismatches over assets equal to zero. In Panel B, Matchings is the size of a sample matched between firms with and without currency mismatches. The matched firms selected are those with the closest propensity score after the sample was restricted to firms in the common support. Investment/K<sub>-1</sub> (Mismatched) and Investment/K<sub>-1</sub> (Not Mismatched) are, respectively, the average investment rates of the groups with and without currency mismatches in the matched sample. Investment Difference/K<sub>-1</sub> is the average effect of the treatment on the treated firms, determined by the difference in the investment rates of the mismatched and matched firms. The confidence intervals (1, 5 and 10%) were calculated by bootstrapping through 1000 replications. We reported the *p*-values in parentheses. (\*\*\*, \*\*, \*) indicate significance at the 1%, 5% and 10% level.

In our second test, we replicate the difference-in-difference test replacing the variable I(Mismatched) by another indicator variable, I(Leveraged), that assumes the value one for the 50% more leveraged firms in December 2001 and zero in the opposite case. We also replace the control variable Total debt over total asset by Currency mismatch over total asset. The results show that there was no significant difference in investment rate around the crisis between the more leveraged firms and the others. Moreover, the coefficient -0.364 of Currency mismatch over assets was significant at 1%.

Another possibility that could be affecting our results is the assumption of the differences-in-differences approach that the crisis affects the treatment and control groups equally. If the groups presented different time trends, then distinct characteristics (possibly not observable) could provoke different reactions to the shocks.

To address the possibility that trends in variables are evolving differently over time between both groups we tested for evidence of greater investment reductions by the firms with mismatches in a period without balance sheet losses. For this, we re-estimated Eq. (3) using the year 2000 as the base year and the year 2001 as a fictitious post-crisis period. If the negative balance sheet effects found in the differences-in-differences estimation resulted from the groups' different trends, we would expect to find greater investment reductions by the mismatched firms than by the matched firms in this "falsification exercise." The results described in Table 8 show that this did not occur. The coefficient of I(Mismatched) was positive and not statistically significant.<sup>24</sup>

## 6. Competitiveness effect

In this section we test the balance sheet effects on a more homogenous subset of our sample: export firms. The advantage of this alternative test is that currency depreciation may affect export firms through both the balance sheet channel and the competitiveness channel. Depreciation increases the competitiveness of goods sold internationally, raising exporters' profit

<sup>24</sup> Table 6, described in the previous subsection, also shows that propensity score matching indicated no significant differences in the investment rates of the treatment and control groups in 2000 and 2001.



**Table 7**  
Leverage Effects.

	$\Delta(\text{Investment rate})$	
	(A)	(B)
I(Mismatched)	-0.071** (0.030)	
I(Mismatched * Leverage)	-0.020 (0.035)	
I(Leveraged)		-0.025 (0.026)
Investment rate	-0.862*** (0.071)	-0.865*** (0.068)
Exports / Total revenue	0.173** (0.078)	0.184** (0.076)
Imports / Total revenue	-0.011 (0.121)	0.025 (0.119)
Operational profit / Total asset	0.100 (0.197)	0.087 (0.194)
$\Delta(\text{Log Sales})$	-0.008 (0.038)	-0.007 (0.035)
Log total assets	-0.002 (0.008)	-0.001 (0.007)
Total debt / Total asset	-0.006 (0.079)	
Currency mismatch / Total asset		-0.364*** (0.101)
Constant	0.090 (0.101)	0.077 (0.097)
Obs.	217	217
R <sup>2</sup>	0.71	0.71

Note: This table contains the results of the least squares estimation of variants of Eq. (2) in the text. The dependent variable is the change in gross investment rate, measured as  $(K(t) - K(t-1) + \text{depreciation}) / K(t-1)$ , in which the capital stock (K) is defined as fixed assets net of depreciation. The year 2001 is used as a base (pre-crisis). The year 2003 is used for the post-crisis data. I(Mismatched) is an indicator variable that takes the value one for firms with currency mismatches exceeding 5.3% of their assets in 2001 and zero in the opposite case. I(Leveraged) is an indicator variable that takes the value one for half of the firms in the sample with higher total debt to total asset ratio. I(Mismatched\*Leverage) is an indicator variable that assumes the value one only for the subset of 50% more leveraged firms in the group of mismatches ones in 2001. Currency mismatch is defined as foreign currency debt net of foreign exchange assets and derivatives. The other control variables are fixed in the base year. Exports and imports were converted into domestic currency using the average exchange rate for each year. Total debt was calculated by the sum of the value of loans and financing in foreign currency and domestic currency, including debentures. Operational profit was calculated before tax and interest. Sales growth rate is measured by the change in the logarithm of total revenue. Sales growth rate is measured by the change in the logarithm of total revenue. Log of total assets is the logarithm of total assets. We used clusters at the firm level to estimate standard errors and to correct possible errors of serial correlation and heteroscedasticity. We reported the robust standard errors in parentheses. (\*\*\*, \*\*, \*) indicate significance at the 1%, 5% and 10% level.

in domestic currency.<sup>25</sup> In this case, if balance sheet effects are relevant, the investments by export firms will rise due to competitiveness gains, and also these increases in investments will be lower for exporters with unhedged foreign currency debt. Among the sample firms, 107 reported positive exports net of imports in December of 2001. Of these, 55 had unhedged foreign currency debt.

Initially we test whether, in fact, the depreciation of 2002 increased exporters' competitiveness, raising their net sales revenue more than that of firms that did not export, as predicted in conventional open economy models. For this we again used the differences-in-differences approach. However, here our treatment group consisted of 107 firms with positive exports net of imports in 2001. The control group consisted of 125 firms with positive imports net of exports or no overseas trade in 2001. These two groups help us to estimate the competitiveness effect of the currency depreciation in the usual way: comparing changes in net revenue (before and after the crisis) of exporting and non-exporting firms.

We would expect that the competitiveness gain should ease credit restrictions and increase investments by exporters as compared to non-exporters. However, the models that take into account balance sheet effects would predict that the rise in exporter investments would be less significant for those with unhedged foreign currency debt and this is different than predictions of investment models based on relative prices.

To test the balance sheet effects, we compared the difference in investment rates (before and after the crisis of 2002) among export firms with and without currency mismatches. In this year, the 55 export firms with currency mismatches before the crisis constituted the treatment group, while the remaining exporters constituted the control group.

<sup>25</sup> The extent of the competitiveness effect depends on the pass through from currency depreciation to domestic prices. In general, empirical studies find that this pass through is incomplete, which ensures competitiveness gains. See, for example, Goldberg and Knetter (1997) and Goldfajn and Werlang (2000).

**Table 8**  
Testing for Trend Differences between the Treatment and Control Groups.

	$\Delta(\text{Investment rate})$	
	(A)	(B)
I(Mismatched)	0.044 (0.121)	0.112 (0.097)
Exports / Total revenue		0.067 (0.174)
Imports / Total revenue		0.583 (0.423)
Operational profit / Total asset		2.645** (1.280)
$\Delta(\text{Log Sales})$		-1.047 (0.648)
Log total assets		-0.003 (0.023)
Total debt / Total asset		-0.193 (0.219)
Constant	-0.151* (0.080)	0.203 (0.321)
Obs.	228	228
R <sup>2</sup>	0.00	0.25

Note: This table contains the results of the least squares estimation of variants of Eq. (4) in the text, except for the period analyzed. In this falsification exercise, we used a period without currency crises. The year 2000 was used as a base period and the year 2001 as the post fictitious crisis period. The dependent variable is the change in gross investment rate, measured as  $(K(t) - K(t-1) + \text{depreciation}) / K(t-1)$ , in which capital stock (K) is defined as fixed assets net of depreciation. I(Mismatched) is an indicator variable that takes the value one for firms with currency mismatches exceeding 5.3% of their assets in 2001 and zero in the opposite case. Currency mismatch is defined as foreign currency debt net of foreign exchange assets and derivatives. The other control variables are fixed in the base year. Exports and imports were converted into domestic currency using the average exchange rate for each year. Total debt was calculated by the sum of the value of loans and financing in foreign currency and domestic currency, including debentures. Operational profit was calculated before tax and interest. Sales growth rate is measured by the change in the logarithm of total revenue. We used clusters at the firm level to estimate standard deviations and to correct possible errors of serial correlation and heteroscedasticity. We reported the robust standard errors in parentheses. (\*\*\*, \*\*, \*) indicate significance at the 1%, 5% and 10% level.

**Table 9**  
Balance Sheet and Competitiveness Effects.

	$\Delta(\text{Log Net Revenue})$		$\Delta(\text{Investment rate})$		
	(A)	(B)	(C)	(D)	(E)
I(Exporters)	0.168 (0.046)**	0.146 (0.049)**	0.072 (0.043)	0.164 (0.048)**	0.109 (0.034)**
I(Exporters * Mismatched)		0.042 (0.073)		-0.176 (0.049)**	-0.125 (0.036)**
Investment rate					-0.857 (0.071)**
Operational profit / Total asset					0.79 (0.195)
$\Delta(\text{Log Sales})$					-0.004 (0.038)
Log total assets					-0.002 (0.008)
Total debt / Total asset					-0.062 (0.063)
Constant	-0.037 (0.027)	-0.037 (0.027)	-0.078 (0.034)*	-0.078 (0.034)*	0.057 (0.106)
Obs.	217	217	217	217	217
R <sup>2</sup>	0.06	0.06	0.01	0.04	0.70

Note: This table contains the results of the least squares estimation of variants of equation (5) in the text. In Columns (A) and (B), the dependent variable is the change in the logarithm of revenue net of sales tax, and in Columns (C) through (E) it is the change in gross investment rate, measured as  $(K(t) - K(t-1) + \text{depreciation}) / K(t-1)$ , in which the capital stock (K) is defined as fixed assets net of depreciation. The year 2001 was used as a base (pre-crisis), and the year 2003 was used for post-crisis data. I(Exporters) is an indicator variable that takes the value one for firms with positive net exports in 2001 and zero in the opposite case. I(Exporters\*Mismatched) is an indicator variable that takes the value one for firms with positive net exports in 2001 and with currency mismatches exceeding 5.3% of their assets in 2001. Currency mismatch is defined as foreign currency debt net of foreign exchange assets and derivatives. The other control variables are fixed in the base year. Exports and imports were converted into domestic currency using the average exchange rate for each year. Total debt was calculated by the sum of the value of loans and financing in foreign currency and domestic currency, including debentures. Operational profit was calculated before tax and interest. Sales growth rate is measured by the change in the logarithm of total revenue. Log of total assets is the logarithm of total assets. We used clusters at the firm level to estimate standard deviations and to correct possible errors of serial correlation and heteroscedasticity. We reported the robust standard errors in parentheses. (\*\*\*, \*\*, \*) indicate significance at the 1%, 5% and 10% level.

The model to be estimated is the following:

$$\begin{aligned} \text{Investment Rate}_{i,2003} - \text{Investment Rate}_{i,2001} = & \delta + \beta I(\text{Exporters})_{i,2001} + \alpha I(\text{Exporters} * \text{Mismatched})_{i,2001} \\ & + \pi_1 \text{Investment Rate}_{i,2001} + \pi_2 (\text{Operacional Profit/Assets})_{i,2001} + \pi_3 \text{Log Assets}_{i,2001} + \pi_4 (\text{Debt/Assets})_{i,2001} \\ & + \varepsilon_{it} \end{aligned} \quad (4)$$

The dependent variable continues to be the variation in gross investment rate for each firm  $i$  in period  $t$ . The variables of interest now are the indicator variables  $I(\text{Exporters})$  and  $I(\text{Exporters} * \text{Mismatched})$ . The first takes the value one for firms with net exports in 2001 and zero in the opposite case. The second assumes the value one only for the subset of firms with mismatches in the group of exporters in 2001.

The coefficient  $\beta$  measures the difference in investment rates of the export and non-export firms between 2001 and 2003; this is our measure of the competitiveness effect. If the competitiveness gains caused by the currency depreciations did in fact increase the firms' investments, we should expect a positive  $\beta$ . The coefficient  $\alpha$  measures the difference in investment rates between exporters with and without mismatches: our measure of the balance sheet effect. If the losses provoked by currency depreciation increased the financing costs of exporters with mismatches more than that of exporters without mismatches, we should expect a negative  $\alpha$ . If the balance sheet effects did not cause exporters with currency mismatches to have more credit restriction in comparison, then  $\alpha$  should be statistically equal to zero.

Column (A) of Table 8 shows that the net revenue of the exporting group rose 16.8% in comparison to the other firms from 2001 to 2003. This coefficient was highly significant ( $p$ -value of 0.001). Column (B) shows that there were no significant differences in revenue gains between the exporters with and without currency mismatches. Therefore, we have significant evidence that the revenue of export firms rises more than that of firms that did not export in the aftermath of currency depreciations.

In Column (C) of Table 9, we show that the competitiveness effect of the currency depreciation of 2002 also positively affected investment. The investment rates of exporters rose 7.2 percentage points more than that of non-exporters. This competitiveness gain would have been even greater if there had not been exporters with large currency mismatches just before the crisis. Column (D) shows that, in 2003, exporters with currency mismatches just before the crisis invested 17.6 percentage points less than exporters without mismatches compared with pre-crisis levels. The group of matched exporters invested 16.4 percentage points more than the non-export firms. Since in this model the change in average investment rate of the sample firms was negative by 7.8 percentage points (captured by the constant  $\delta$ ), we have evidence that the average investment rate of the exporters rose 8.6 percentage points between 2001 and 2003. On the other side, the investment rates of the exporters with mismatches, on average, fell 9 percentage points.<sup>26</sup>

Lastly, we re-estimated the model introducing the variables that control selection biases. The results, described in Column (E), did not change qualitatively. The balance sheet effect impacted investment more than the competitiveness effect for firms influenced by these two effects: the exporters with currency mismatches. The difference in investment rates of export and non-export firms was 10.9 percentage points. In the exporting group, the investment rates of those with mismatches fell 12.5 percentage points more than the rate of those without mismatches. Both coefficients were significant at 1%. The only significant control variable in this model was the investment rate of the base period.

In summary, we may extract two basic conclusions from this section. First, that competitiveness gains are quite substantial after dramatic currency depreciation. Second, the increase in revenues for exporters was not enough to fully counteract the negative effects of balance sheet losses. The natural hedge provided by exports was not sufficient.

## 7. Conclusion

In third generation models of currency crises, the balance sheet losses of firms with unhedged foreign currency debt exercise a central role in explaining the recessionary effects of the crises. However, empirical evidence that tests the relevance of these models is not conclusive. While in some countries there is evidence that having debt in foreign currency lowers investment by firms following currency depreciation, in others the evidence is not significant or even shows increased investment.

In this article, we test the importance of this balance sheet channel, combining a more precise, firm-level measure of currency mismatches with an analysis focusing on the Brazilian currency crisis of 2002. This crisis was related to the presidential election campaign gives the exchange rate depreciation a more experimental character than is typically the case. To isolate the balance sheet effects from other macroeconomic events that could have influenced investment after the crisis, we identified two groups of firms: the treatment group, which was formed of firms with currency mismatches just before the crisis of 2002 and thus reported balance sheet losses; and the control group, which was formed of firms that did not have currency mismatches. While the treatment group's investment changes (before and after the crisis) should reflect both the balance sheet effect and other effects of the 2002 crisis, the control group's changes should reflect only these other

<sup>26</sup> The change in the investment rate of export firms was calculated by the sum of coefficients  $\delta$  and  $\beta$  in equation (4). In the case of exporters with mismatches, the change is calculated by the sum of coefficients  $\delta$ ,  $\alpha$  and  $\beta$ .

effects, which impacted all firms alike. Therefore, the difference in the changes in these two groups gives us an estimate of the balance sheet effect of currency depreciation on the firms' investment rates.

We found that firms with currency mismatches reduced investments more than firms without mismatches an average of 8.1 percentage points in the first year after the currency shock and 5.5 percentage points the second year. These negative balance sheet effects were also quite substantial when we used propensity score matching to select a sample of firms without currency mismatches that was most similar to the firms with currency mismatches just before the crisis. The economic significance of these balance sheet effects is considerable given that the average investment rate of all firms was 8.1% in 2001.

Lastly, we conducted a joint test of the balance sheet and competitiveness effects of the currency depreciation on investment by analyzing the investment rate changes of exporters before and after the currency crisis of 2002. The results show that competitiveness gains were expressive with the exporters' revenue and investment rates rising 16.8% and 10.9 percentage points more than non-exporters' investments, respectively. However, confirming the importance of the negative balance sheet effects, the exporters with currency mismatches invested 12.5 percentage points less than exporters that did not report balance sheet losses related to the currency depreciation.

In summary, the evidence for the Brazilian currency crisis of 2002 shows that the negative balance sheet effects can reverse the competitiveness effect of the currency depreciations, thus capable of making the currency crisis contractionary.

## Appendix A

**Table A1**  
Number of Firms in the Sample per Sector.

Sector / Year	2000	2001	2002	2003	2004
Total	224	232	228	217	197
Food and Beverages	14	14	14	15	12
Commerce	9	10	10	9	8
Civil Construction	13	13	11	12	10
Electro-Electronics	9	10	9	9	8
Energy	27	26	26	28	26
Industrial Machinery	9	8	9	7	6
Mining	3	3	3	3	3
Non-Metallic Minerals	6	6	6	5	4
Paper and Pulp	8	9	9	9	8
Oil and gas	8	8	8	7	6
Chemical	18	18	17	16	17
Steel and Metallurgy	26	27	25	25	25
Telecommunications	19	21	23	15	13
Textiles	21	20	20	20	18
Transportation Services	2	3	2	3	1
Veichles and Parts	12	12	12	11	12
Others	20	24	24	23	20

Note: The industry divisions are those used by Economática to classify publicly held Brazilian firms. As there was only one firm in the Agri and Fisheries sector, we included it in the Food and Beverage sector.

**Table A2**  
Balance Sheet Effects on Investment: Differences-in-differences.

	$\Delta(\text{Investment rate})$	
	(A)	(B)
I(Mismatched)	−0.066** (0.026)	−0.087* (0.052)
Investment rate	−0.856*** (0.072)	−0.872*** (0.070)
Exports / Total revenue	0.169** (0.079)	0.185** (0.084)
Imports / Total revenue	−0.066 (0.116)	−0.155 (0.164)
Operational profit / Total asset	0.169 (0.200)	0.057 (0.172)
Sales Growth Rate	0.008 (0.035)	−0.010 (0.043)
Log total assets	−0.003 (0.007)	−0.008 (0.010)
Total debt / Total asset	−0.015 (0.015)	−0.101 (0.139)
Constant	0.092 (0.095)	0.231 (0.150)
Obs.	235	227
R <sup>2</sup>	0.68	0.36

Note: This table contains the results of the least squares estimation of variants of Eq. (4) in the text. The dependent variable is the change in gross investment rate, measured as  $(K(t) - K(t-1) + \text{depreciation}) / K(t-1)$ , in which the capital stock (K) is defined as fixed assets net of depreciation. The year 2001 is used as a base (pre-crisis). The year 2003 is used for the post-crisis data. The sample used in Column (A) includes the 30 firms that were probably in financial distress before the crisis of 2002 and, in column (B), the 54 observations that we had identified changes in capital that were not directly related to currency depreciation. I(Mismatched) is an indicator variable that takes the value one for firms with currency mismatches exceeding 5.3% of their assets in 2001 and zero in the opposite case. Currency mismatch is defined as foreign currency debt net of foreign exchange assets and derivatives. The other control variables are fixed in the base year. Exports and imports were converted into domestic currency using the average exchange rate for each year. Total debt was calculated by the sum of the value of loans and financing in foreign currency and domestic currency, including debentures. Operational profit was calculated before tax and interest. Sales growth rate is measured by the change in the logarithm of total revenue. Sales growth rate is measured by the change in the logarithm of total revenue. Log of total assets is the logarithm of total assets. We used clusters at the firm level to estimate standard errors and to correct possible errors of serial correlation and heteroscedasticity. We reported the robust standard errors in parentheses. (\*\*\*, \*\*, \*) indicate significance at the 1%, 5% and 10% level.

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