Empir Econ (2019) 57:449–473
https://doi.org/10.1007/s00181-018-1459-y

Balance sheet and currency mismatch: evidence for Peruvian firms

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Received: 29 June 2016 / Accepted: 18 April 2018 / Published online: 31 May 2018
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Abstract In the Peruvian economy, as in other emerging economies, a significant portion of the debt held by firms is denominated in US dollars. While an exchange rate depreciation is likely to increase firm debt and influence investment and production plans, the literature finds weak or no evidence of this balance sheet effect. In this paper, I argue that this effect is observed in firms with a significant currency mismatch. I estimate the currency mismatch (defined as assets minus liabilities in US dollars and expressed as a percentage of total assets in domestic currency) from which the exchange rate has negative effects on firms' investment. Using financial information from 74 non-financial Peruvian firms from 2002 to 2014, I find significant balance sheet effects for firms with a currency mismatch below −10.4%.

Keywords Balance sheet · Dollar debt · Peru

1 Introduction

Since the recovery of the US economy and the beginning of the normalization period of US monetary policy, the US dollar has strengthened worldwide. In this context, the Peruvian sol (domestic currency) has depreciated against the US dollar since 2013. As in conventional open economy models (Mundell–Fleming type), a local currency depreciation has a positive effect on the product because exported products become relatively cheaper and the country thus becomes more competitive in international markets.

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In the Peruvian economy, as in other emerging economies, a significant portion of the debt held by firms is denominated in US dollars (approximately 40%), even when firms generate income in domestic currency. Exchange rate depreciation increases the debt-to-asset ratio, making access to alternative sources of financing more difficult. Thus, for firms in the private sector, these balance sheets negatively affect investment and production plans and may lead to a contractive effect at the aggregate level.

Theoretically, a large body of the literature has built upon the work of Bernanke et al. (1999), which includes imperfections in the domestic financial market within an open economy model. In the models presented in this literature, if there is a significant currency mismatch in the economy, a large devaluation will deteriorate a firm's net worth. Using this balance sheet channel, Krugman (1999), Aghion et al. (2001), and Orrego and Gondo (2016) present models with multiple equilibrium. Further literature on liability dollarization and currency mismatch has suggested that a balance sheet effect induced by exchange rate depreciations could explain this negative impact (see Cespedes et al. 2004; Choi and Cook 2004; Magud 2010; Ize and Levy-Yeyati 2006; Batini et al. 2007; Bleakley and Cowan 2008; Carranza et al. 2009).

Empirical analyses, however, have found only weak evidence for this effect (see for a review Luengnaruemitchai 2003), and usually only in the context of rather large depreciations (see, among others, Burstein et al. 2005; Galindo et al. 2003; Leiderman et al. 2006). These empirical findings suggest that the aggregate investment function may present a nonlinearity in its dependence on the real exchange rate. For the Peruvian economy, Carranza et al. (2011) show that the negative balance sheet effect of an exchange rate depreciation may only be observable if the magnitude of the depreciation is large enough; while Azabache (2010) shows that the negative effects depend on a firm's leverage level, and Loveday et al. (2004) find negative effects through the interaction between leverage and exchange rate depreciation.

If firms also hold assets and/or have income in US dollars that match their currency composition, then movements in the exchange rate should not affect their investment decisions. Although firms exhibit currency mismatch in the composition of their currencies, they could use derivatives to hedge undesired movements in the exchange rate; or they could repurchase their own debt in US dollars by issuing new debt in Peruvian soles. Nonetheless, in the financial statements of Peruvian firms, most of those that held liabilities in US dollars indicated that they did not use derivatives. Also, the Financial Stability Report (2015) of the Central Bank of Peru states that it has observed firms with currency mismatches; most of these firms are oriented to the domestic market, have borrowed in US dollars (whether in the local market or abroad), and have not taken derivatives. Thus, the threshold level of currency mismatch at which the exchange rate has negative effects on firms is relevant for the Peruvian economy.

In this paper, I argue that the balance sheet effect: (1) depends on the currency mismatch level; and (2) is observed in the context of a large negative currency mismatch, where debt in foreign currency exceeds significant assets in foreign currency. I base these arguments on the nonlinear effects suggested by theory and empirics and seek to prove them by estimating a threshold currency mismatch in which the balance sheet effect dominates the competitiveness effect. The remainder of this paper is organized as follows: Sect. 2 discusses empirical methodology such as specification, data, and estimation methods; Sect. 3 presents the empirical results and estimations of the threshold models; Sect. 4 concludes.

2 Empirical methodology

2.1 Model specification

Strong evidence suggests that a firm's investment activity depends on exchange rate movements and that this relationship will be positive if the competitiveness effect dominates the balance sheet effect, and negative otherwise (see Carranza et al. 2003; Bleakley and Cowan 2008). Therefore, an initial specification is given by

$$I_{it} = \beta q_t + \alpha_i + \pi' z_{it} + u_{it}, \tag{1}$$

where I is the investment; q is the bilateral (Pen/USD) real exchange rate variation; α_i is an unobserved firm-specific effect (assumed to be fixed as is common in empirical applications); z is a set of other determinants (controls) of investment; i refers to non-financial firm; and t refers time (year).

However, the impact depends on the relative strength of the competitiveness effect and the balance sheet effect. As in Carranza et al. (2003), this effect can be decomposed as

$$\delta\beta = \delta + \theta D^*_{it-1} + \lambda X_{it}, \tag{2}$$

where D^* is the firm's liability denominated in foreign currency or US dollar debt and X is the firm's net export. Plugging (2) into (1) produces

$$I_{it} = \theta(D^*_{it-1} \times q_t) + \lambda(X_{it} \times q_t) + \delta q_t + \alpha_i + \pi' z_{it} + u_{it}. \tag{3}$$

Empirical analyses focused on the parameter θ, reveal that if this parameter is negative, evidence exists for the balance sheet effect. Nonetheless, empirical studies found little evidence or no evidence on the negative significance of such parameter (see Bleakley and Cowan 2008; Carrera 2016). This result exists because firms also hold assets and/or have income in US dollars that match their currency composition; thus, movements in the exchange rate should not affect their investment decisions.

In this paper, I argue that the balance sheet effect is observed in the context of large negative currency mismatch, where debt in foreign currency exceeds significant assets in foreign currency.[1] Thus, I estimate a threshold currency mismatch level from which the parameter θ is negative and significant. I estimate the following variation of an investment model with a threshold variable,

[1] Cowan et al. (2005) in a linear model include controls for the currency composition of assets and net derivative positions of Chilean corporations between 1994 and 2001. They found, once the currency composition of assets and income is accounted for, a significant negative balance sheet effect of US dollar-denominated debt.

$$\begin{aligned} I_{it} = {} & \theta_1(D^*_{it-1} \times q_t)1(CM_{it} \leq \gamma) + \theta_2(D^*_{it-1} \times q_t)1(CM_{it} > \gamma) \\ & + \lambda(X_{it} \times q_t) + \delta q_t + \alpha_i + \pi' z_{it} + u_{it}, \end{aligned} \quad (4)$$

where CM is the currency mismatch; θ_1 captures the negative effect of the balance sheet effect; θ_2 is the parameter in the second regime when firms have a low mismatch in their currency composition and could hedge exchange rate risk; γ is a threshold currency mismatch level; $1(.)$ is an indicator variable; and δ, λ and π are other parameters to be estimated.

2.2 Control variables

Alongside the competitive and balance sheet effects of the exchange rate on a firm's investment, I consider a set of explanatory control variables divided into two groups: The first group is related to the firm's specific variables such as size, cash flow, dollar debt, total debt, working capital, leverage, and sales growth. A firm's investment is shaped not only by internal factors, but also by external macroeconomic conditions; thus the second group is related to macroeconomic conditions such as terms of trade, dollarization ratio, and domestic interest rate.

Firm-specific control variables

The first variable considered is cash flow. A firm's investment might increase when cash flow is high because of the lesser costs of using internal rather than external funds, overspending of internal funds by the managers, or a plain correlation of cash flows and investment opportunities (Lewellen and Lewellen 2016). Empirically, Kaplan and Zingales (1997) argue that the relationship between investment and cash flow depends on the financing constraints, while Kadapakkam et al. (1998) argue that this relationship depends on firm size.

The second variable is working capital, which is the amount of liquid assets used by a firm for day-to-day financial operations and is therefore an important measure of its liquidity. The decline in working capital, such as at times of crisis, involves a fall in internal funds and an increase in the cost of external funds (Hall and Kruiniger 1995); thus, it directly affects investments and their timing, depending on whether the firm is financially constrained. Moreover, Fazzari and Petersen (1993) view the working capital as a smoothing factor of investment in the face of a cash flow shock.

The third variable considered is firm size. On the one hand, Kurshev and Strebulaev (2015) argue that larger firms have greater and cheaper access to outside financing and portfolio diversification. Similarly, Fazzari et al. (1988) find that small firms in the USA were less likely to be able to obtain capital at market interest rates, and thus were subject to greater credit restrictions. Meanwhile, Gala and Julio (2016) argue that just as the literature on economic growth applies the notion of convergence to countries, so too can it be applied to any economic unit; in the case of US firms, they find that small firms have significantly higher investment rates than large ones. Another channel is identified by Beck et al. (2008), who argue that faster financial development removes growth and financial constraints on small firms, and thus small firms tend to invest more.

The fourth control variable considered is leverage. High leverage reduce a firm's ability to finance investment through a liquidity effect, because managers of firms with good growth opportunities choose low leverage; in other words, firms with high leverage might not be able to take advantage of growth opportunities (Lang et al. 1996), thus reducing investment. Lang et al. (1996) show that there is a negative relationship between leverage and investment in the case of industrial firms.

The fifth variable in this area is total debt; debt is a great substitute for internal funds in financing investment; in addition, it reduces the cash flow available for discretionary use and therefore the agency costs of free cash flow (Jensen 1986). In turn, Whited (1992) presents evidence to support the theory that problems of asymmetric information in debt markets financially affect the ability of unhealthy firms to obtain outside finance and, consequently, their allocation of investment expenditure.

The final variable considered is real sales growth, which is used here as a measure of performance, and is expected to have a positive effect on investment since it increases the internal availability of funds for investment spending. In addition, an observed increase in demand pushes up production inputs and capital. For example, Grazzi et al. (2016) finds that sales growth has a positive effect on the probability of a large investment in the subsequent year for France and Italy, consistent with the need for an expansion of capacity to meet growing demand.

Macroeconomic control variables

The first variable in this area is terms of trade. The works of Laursen and Metzler (1950) and Harberger (1950) introduced what is known as the Laursen-Metzler effect, which proposes that a deterioration in the terms of trade faced by a small open economy lends itself to lower levels of income, savings, and investment. This variable is important in emerging, commodity-exporting economies: mineral exports account for approximately 40 percent of all exports in Peru.

The second variable in this area is aggregate dollarization. When an economy is dollarized its monetary authority gives up control of the monetary policy, and capital mobility and global financial integration increase (Berg and Borensztein 2000). This has mixed consequences, as access to outside capital could promote efficient allocation of resources, but at the same time the economy is more vulnerable to exchange rate volatility and external negative shocks such as financial crises. Thus, when uncertainty decreases due to lower aggregate dollarization, firms tend to invest more. In Peru, aggregate dollarization has been decreasing, going from 76% in 2002 to 38% in 2014.

The final variable considered in this area is the interest rate. To make investment decisions, firms evaluate projects. The investment is made today, while the flows of benefits, discounted by the interest rate, are received in the future. Therefore, an increase in the interest rates reduces the profitability of the firm's prospective projects, and thus the level of investment should fall.

Table 1 Definitions

Variable	Definition
Investment	Investment is the expenditure in machinery and equipment net of fixed asset sales divided by total assets
US dollar debt	Total liabilities in foreign currency expressed in terms of domestic currency as a percentage of total liabilities
Currency mismatch	Total assets minus liabilities in US dollars expressed as a percentage of total assets in domestic currency
Cash flow	Cash flow divided by total assets
Working capital	Difference between current assets and current liabilities divided by total assets
Firm size	Total sales in logarithm
Leverage	Total liabilities divided by equity
Net export	Difference between export and import at FOB prices divided by total assets
Total debt	Total debt divided by total assets
Sales growth	Growth of total sales in real terms
Real exchange rate	Growth of the bilateral rate Peruvian sol per US dollar divided by consumer price index (CPI)
Terms of trade	Terms of trade growth
Dollarization ratio	Credit in US dollar expressed in terms of domestic currency divided by total credit of depositary corporations to the private sector
Domestic interest rate	Lending interest rates of commercial banks in domestic currency (annual effective rates)

All firm variables were deflated by the consumer price index

2.3 Data

The period of study spans from 2002 to 2014 for a sample of 74 non-financial firms. Data are constructed manually from the firms' financial information available from the *Superintendencia de Mercado de Valores*. Firms are distributed in the following sectors: manufacture (42%), services (26%), mining (14%), construction (8%), commerce (7%) and agriculture (4%). Table 1 shows constructions and definitions of the variables used in the estimation analysis.

As in Carranza et al. (2003) and Azabache (2010), I do not take information on the change in net fixed assets from the balance sheet; as those authors mention, change in net fixed assets include changes in valuation of asset values, which are not related to capital expenditure but rather to firm-specific accounting practices. In addition, data of firms' imports and exports are taken from the *Superintendencia Nacional de Administración Tributaria*. Macroeconomic variables are taken from the Central Bank of Peru.[2] Summary statistics of the variables involved in the estimation analysis are given in Table 2.

[2] It is important to notice that I consider a balanced data since it is required for estimation method.

Table 2 Summary statistics

Variable	Minimum	25% quantile	Median	75% quantile	Maximum
Investment	– 30.2	1.1	3.2	6.1	41.0
US dollar debt	0.0	17.9	50.2	71.0	100.0
Currency mismatch	– 62.3	– 15.0	– 3.3	3.4	99.1
Cash flow	– 116.7	– 1.1	0.2	2.0	47.1
Working capital	– 88.4	– 0.1	9.6	23.7	79.9
Firm size	4.2	7.4	8.4	9.8	12.6
Leverage	0.2	34.7	70.1	110.5	912.4
Net export	– 103.8	– 4.0	0.0	0.0	215.8
Total debt	0.2	25.6	40.8	52.1	90.1
Sales growth	– 603.6	– 3.4	6.3	17.4	625.3
Real exchange rate	– 8.3	– 3.4	– 1.7	0.5	3.4
Terms of trade	– 11.3	– 2.3	4.5	7.3	27.9
Dollarization ratio	39.3	44.1	52.4	68.5	77.7
Domestic interest rate	15.7	19.0	21.0	23.7	25.5

Since all firm variables except firm size are ratios, the variables included in the estimation analysis ought to be stationary; Table 3 shows a set of unit root tests developed for panel data; Baltagi and Kao (2000) provide an excellent survey of this literature. As expected, most of the tests indicate that the firm's variables are indeed stationary, except firm size (only the Levin, Lin and Chu test indicates that this variable is stationary). However, an asymptotic theory of threshold models and dynamic models in panel data was developed for a large number of individuals (firms) and short time periods; thus, consistency estimates are not affected by the non-stationarity of the regressors.

Macroeconomic variables affect a firm's investment as a whole; since there are only 13 time observations, I do not conduct time series unit root tests, since such test perform poorly in small sample sizes. Nonetheless, even though there is a debate regarding whether exchange rate and terms of trade levels are stationary or non-stationary variables, the growth rate of such series are stationary variables. Aggregate dollarization is the credit in US dollar to total credit ratio, and thus fluctuates between 0 and 100%; similarly, the domestic interest rate fluctuates around its mean; hence, both variables are expected to be stationary variables.

Table 4 shows pairwise correlations among the firm variables included in the estimation analysis; pairwise correlations among regressors are below 0.5, except for total debt and leverage, which are highly correlated (0.87), indicating redundant control variables. Thus, in the next sections, I include only one of them is in the estimations since both measure debt.

As regards the macroeconomic variables, Model (4) implies the main effects of the interaction between exchange rate depreciation and US dollar debt, and the exchange rate depreciation itself. Correlations among most macroeconomic variables are less than 0.5—that is, correlation between exchange rate and dollarization is 0.14; between

Table 3 Panel unit root tests (p-values)

Method	Investment	US dollar debt	Currency mismatch	Cash flow	Working capital
Null hypothesis: unit root (assumes individual unit root process)					
Im, Pesaran and Shin W-stat	0.0000	0.0003	0.0000	0.0000	0.0000
ADF—Fisher Chi-square	0.0000	0.0000	0.0000	0.0000	0.0000
PP—Fisher Chi-square	0.0000	0.0000	0.0000	0.0000	0.0000
Null hypothesis: Unit root (assumes common unit root process)					
Levin, Lin and Chu t-stat	0.0000	0.0000	0.0000	0.0000	0.0000
Breitung t-stat	0.0000	0.9236	0.0004	0.0000	0.9986

Method	Firm size	Leverage	Net export	Total debt	Sales growth
Null hypothesis: unit root (assumes individual unit root process)					
Im, Pesaran and Shin W-stat	0.5916	0.0006	0.0000	0.0016	0.0000
ADF—Fisher Chi-square	0.6438	0.0000	0.0000	0.0002	0.0000
PP—Fisher Chi-square	0.6166	0.0000	0.0000	0.0000	0.0000
Null hypothesis: unit root (assumes common unit root process)					
Levin, Lin and Chu t-stat	0.0000	0.0000	0.0000	0.0000	0.0000
Breitung t-stat	0.7668	0.9637	0.2652	0.9536	0.0000

The specification of the unit root tests includes individual effects and individual linear trends. ADF for Augmented Dickey–Fuller and PP for Phillips Perron

Table 4 Correlations

	Investment	US dollar debt	Currency mismatch	Cash flow	Working capital	Firm size	Leverage	Net export	Total debt
US dollar	−0.0240								
Debt	(0.0323)								
Currency	−0.0026	−0.0359							
Mismatch	(0.0323)	(0.0323)							
Cash	−0.0411	−0.0567	0.1407						
Flow	(0.0322)	(0.0322)	(0.0320)						
Working	−0.1303	0.2010	0.3673	0.1502					
Capital	(0.0320)	(0.0316)	(0.0300)	(0.0319)					
Firm	0.1708	−0.1432	−0.0620	0.0250	−0.2714				
Size	(0.0318)	(0.0319)	(0.0322)	(0.0323)	(0.0311)				
Leverage	0.1315	−0.0018	−0.3487	−0.0363	−0.4145	0.2605			
	(0.0320)	(0.0323)	(0.0302)	(0.0323)	(0.0294)	(0.0312)			
Net	−0.0306	0.0679	0.2026	0.0381	0.0187	0.0077	−0.0569		
Export	(0.0336)	(0.0335)	(0.0329)	(0.0336)	(0.0336)	(0.0336)	(0.0335)		
Total	0.1904	0.0060	−0.4195	−0.0564	−0.4770	0.3697	0.8741	−0.0732	
Debt	(0.0317)	(0.0323)	(0.0293)	(0.0322)	(0.0284)	(0.0300)	(0.0157)	(0.0335)	
Sales	0.0911	0.0081	−0.0659	0.0181	−0.0212	0.0194	0.0406	0.0096	0.0423
Growth	(0.0335)	(0.0336)	(0.0335)	(0.0336)	(0.0336)	(0.0336)	(0.0336)	(0.0336)	(0.0336)

Standard errors are in parentheses

exchange rate and terms of trade, 0.03; between exchange rate and domestic interest rate, -0.30; between terms of trade and dollarization, 0.31; and between terms of trade and domestic interest rate, 0.49.

The correlation between dollarization and domestic interest rate is more than 0.5 (0.67) but this is because there are only 13 observations over time, since the correlations are quite sensitive to the small sample size; indeed, the correlation between these variables is 0.28 for the 1992–2014 sample. It is worth mentioning that the macroeconomic control variables (terms of trade growth, dollarization ratio, and domestic interest rate) do not measure the same economic effect on a firm's investment as was highlighted in Sect. 2.2.

3 Estimation and inference in threshold models

Threshold models have proven enormously influential in economics and especially popular in current applied econometric practice. The model splits the sample into classes based on the value of an observed variable, whether or not it exceeds some threshold; that is, the model internally sorts the data into groups of observations based on some threshold determinant, where each group obeys the same model. Hansen (1999) extended those models to a static panel data model, where a least squares (LS) estimation is proposed using fixed-effects transformation.

Before to go over the estimation details, it is convenient to write the model using a compact notation. Thus, another compact representation of (4) is to set

$$d_{it}(\gamma) = \begin{bmatrix} (D^{*}_{it-1} \times q_t)1(CM_{it} \leq \gamma) \\ (D^{*}_{it-1} \times q_t)1(CM_{it} > \gamma) \end{bmatrix}.$$

Assuming for simplicity that there are no control variables and $\theta = (\theta_1, \theta_2)'$. Then, Eq. (4) equals

$$I_{it} = \alpha_i + \theta' d_{it}(\gamma) + u_{it}. \tag{5}$$

3.1 Estimation

One traditional method to eliminate the individual fixed-specific effect α_i is to remove individual-specific means. While straightforward in linear models, the threshold specification (5) calls for a more careful treatment. Similar Hansen (1999), we take averages over the time index t produces

$$\overline{I}_i = \alpha_i + \theta' \overline{d}_i(\gamma) + \overline{u}_i, \tag{6}$$

where $\overline{I}_i = T^{-1}\sum_{t=1}^{T} I_{it}$, $\overline{u}_i = T^{-1}\sum_{t=1}^{T} u_{it}$ and

$$\overline{d}_i(\gamma) = \frac{1}{T}\sum_{t=1}^{T} d_{it}(\gamma)$$
$$= \begin{pmatrix} \frac{1}{T}\sum_{t=1}^{T}(D^*_{it-1} \times q_t)1(CM_{it} \leq \gamma) \\ \frac{1}{T}\sum_{t=1}^{T}(D^*_{it-1} \times q_t)1(CM_{it} > \gamma) \end{pmatrix}.$$

Taking the difference between (5) and (6) yields

$$I^*_{it} = \theta' d^*_{it}(\gamma) + u^*_{it}, \tag{7}$$

where $I^*_{it} = I_{it} - \overline{I}_i$, $d^*_{it}(\gamma) = d_{it}(\gamma) - \overline{d}_i(\gamma)$ and $u^*_{it} = u_{it} - \overline{u}_i$.

Let

$$I^*_i = \begin{bmatrix} I^*_{i2} \\ \vdots \\ I^*_{iT} \end{bmatrix},\ d^*_i(\gamma) = \begin{bmatrix} d^*_{i2}(\gamma) \\ \vdots \\ d^*_{iT}(\gamma) \end{bmatrix},\ u^*_i = \begin{bmatrix} u^*_{i2} \\ \vdots \\ u^*_{iT} \end{bmatrix}$$

denote the stacked data and errors for an individual, with one time period deleted. Then let

$$I^* = \begin{bmatrix} I^*_1 \\ \vdots \\ I^*_i \\ \vdots \\ I^*_n \end{bmatrix},\ d^*(\gamma) = \begin{bmatrix} d^*_1(\gamma) \\ \vdots \\ d^*_i(\gamma) \\ \vdots \\ d^*_n(\gamma) \end{bmatrix},\ u^* = \begin{bmatrix} u^*_1 \\ \vdots \\ u^*_i \\ \vdots \\ u^*_n \end{bmatrix}.$$

Using this notation, (7) is equivalent to

$$I^* = d^*(\gamma)\theta + u^*, \tag{8}$$

given γ, the conditional least square (CLS) estimator for θ is

$$\widehat{\theta}(\gamma) = (d^*(\gamma)' d^*(\gamma))^{-1} d^*(\gamma)' I^*. \tag{9}$$

The vector of regression residuals is

$$\widehat{u}^*(\gamma) = I^* - d^*(\gamma)\widehat{\theta}(\gamma), \tag{10}$$

and the sum of squared errors is

$$S(\gamma) = \widehat{u}^*(\gamma)'\widehat{u}^*(\gamma). \tag{11}$$

Chan (1993) and Hansen (1999) recommend estimation of the threshold parameter γ by conditional least squares. Then, we define the estimator of γ as the value that minimizes (11). Since the criterion function (11) is not smooth, conventional gradient algorithms are not suitable for its minimization. Hansen (1999, 2000) suggests using a grid search over the threshold variable (the measure of the currency mismatch) space. That is, construct an evenly spaced grid on the empirical support of the currency mismatch variable CM. Finally, once $\widehat{\gamma}$ is obtained, the slope coefficient estimate is $\widehat{\theta} = \widehat{\theta}(\widehat{\gamma})$.

3.2 Inference

In threshold regression models, it is known that threshold estimate is superconsistent. Since the sum of squared errors (the objective function) is not smooth, it is found that the distribution of the threshold estimate is non-standard. Meanwhile, the slope parameters are consistent and asymptotically normally distributed (see Chan 1993; Hansen 2000).

Hansen (2000) developed an asymptotic distribution for the threshold parameter estimate based on the small threshold effect assumption, in which the threshold model becomes the linear model asymptotically. The limiting distribution converges to a function of a two-sided Brownian motion process, where the distribution can be available in a simple closed form. Basically, Hansen (2000) argues that the best way to form confidence intervals for the threshold is to form the no-rejection region using the likelihood ratio statistic for testing on $\widehat{\gamma}$. To test hypothesis $H_0 : \gamma = \gamma_0$ (γ_0 is the true value of the threshold parameter), the likelihood ratio test is to reject large values of $LR(\gamma_0)$ where

$$LR(\gamma) = nT\frac{S(\gamma) - S(\widehat{\gamma})}{S(\widehat{\gamma})}, \tag{12}$$

where $S(\gamma)$ is the sum of squared residuals, n is the number of firms and T is the number of periods. Hansen (1996) shows the $LR(\gamma)$ converges in distribution to ξ as $n \to \infty$, where ξ is a random variable with distribution function $P(\xi \leq z) = (1-exp(-z/2))^2$. Then, the asymptotic distribution of the likelihood ratio statistic is non-standard, yet free of nuisance parameters. Since the asymptotic distribution is pivotal, it may be used to form valid asymptotic confidence intervals. Furthermore, the distribution function ξ has the inverse

$$c(a) = -2\ln\left(1 - \sqrt{1-a}\right), \tag{13}$$

where a is the significance level. To form an asymptotic confidence interval for γ, the "no-rejection region" of confidence level $1 - a$ is the set of values of γ, such that $LR(\gamma) \leq c(a)$, where $LR(\gamma)$ is defined in (12) and $c(a)$ is defined in (13). This is easiest to find by plotting $LR(\gamma)$ against γ and drawing a flat line at $c(a)$.

3.3 Test for threshold effects

It is important to determine whether the threshold effect is statistically significant. The hypothesis of no threshold effect in (4) can be represented by the linear constraint

$\theta_1 = \theta_2$. Under the null hypothesis, the threshold γ is not identified, so classical tests have non-standard distributions. Thus, Hansen (1996) proposed a likelihood ratio, F, test and suggested a bootstrap to simulate the asymptotic distribution of the test.

Under the null hypothesis of no threshold, the model is

$$I_{it} = \alpha_i + \theta_1 d_{it} + u_{it}, \tag{14}$$

where $d_{it} = D^*_{it-1} \times q_t$. After the fixed-effect transformation is made, we have

$$I^*_{it} = \theta_1 d^*_{it} + u^*_{it}. \tag{15}$$

The regression parameter θ_1 is estimated by OLS, yielding estimate $\tilde{\theta}_1$, residuals $\tilde{u}^*_{it}$ and sum of squared errors $S_0 = \tilde{u}^{*\prime}_{it}\tilde{u}^*_{it}$. The likelihood ratio test statistics of H_0 is defined as

$$F = n(T-1)(S_0 - S(\widehat{\gamma}))/S(\widehat{\gamma}). \tag{16}$$

Rejection of the null hypothesis suggests the existence of more than one regime. Hansen (1999) argues that the asymptotic distribution of F is non-standard, and strictly dominates the χ^2_k distribution and it appears to depend in general upon moments of the sample and thus critical values cannot be tabulated. Hansen (1996) shows that a bootstrap procedure attains the first-order asymptotic distribution, so p-values constructed from the bootstrap are asymptotically valid, then the asymptotic distribution can be approximated by the following bootstrap procedure.

Similar to Hansen (1999), take the regression residuals $\widehat{u}^*_{it}$ and group them by individual: $\widehat{u}^*_i = (\widehat{u}^*_{i1}, \widehat{u}^*_{i2}, \ldots, \widehat{u}^*_{iT})$. Treat the sample $\{\widehat{u}^*_1, \widehat{u}^*_2, \ldots, \widehat{u}^*_n\}$ as the empirical distribution to be used for bootstrapping. Draw (with replacement) a sample of size n from the empirical distribution and use these errors to create a bootstrap sample under H_0 (notice that the test statistic F does not depend on the parameter θ_1 under H_0, so any value of θ_1 may be used). Using the bootstrap sample, estimate the model under the null (15) and alternative (7) and calculate the bootstrap value of the likelihood ratio statistic F (16). Repeat this procedure a large number of times to calculate the percentage of draws for which the simulated statistic exceeds the actual value. The null is rejected if this p-value is smaller than the desired critical value.

4 Empirical results

4.1 Threshold parameter estimation

The point estimate of the threshold and its asymptotic 90, 95 and 99% confidence intervals are reported in Table 5. The estimate of the threshold level of currency mismatch (total assets minus liabilities in US dollars expressed as a percentage of total assets in domestic currency) is -10.4%. Thus, the two classes of regimes indicated by the point estimate are those with a "large negative currency mismatch" for currency mismatch lower than -10.4%, and a "moderate currency mismatch" for currency

Table 5 Asymptotic confidence interval in threshold model

	Threshold estimate (%)	90% confidence interval	95% confidence interval	99% confidence interval
$\widehat{\gamma}$	− 10.4	[− 10.9, − 2.9]	[− 28.8, 0.1]	[− 30.4, 3.9]

Asymptotic critical values are reported in Hansen (2000)

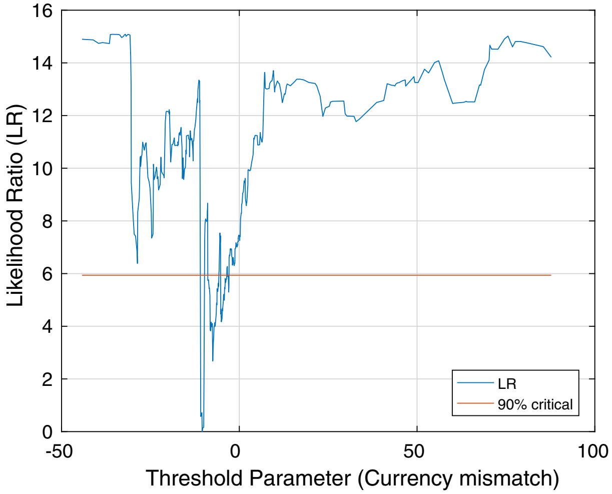

Fig. 1 Confidence interval construction

mismatch higher than − 10.4%. The asymptotic confidence interval for the threshold level is tight, indicating low uncertainty about the nature of this division.[3]

More information can be discerned about the threshold estimates from plots of the concentrated likelihood ratio function $LR(\gamma)$. Figure 1 shows the likelihood ratio function, which is computed when estimating a threshold model. The threshold estimate is the point where the $LR(\gamma)$ equals zero, which occurs at $\hat{\gamma} = -10.4\%$. The confidence level is defined as the values of the threshold parameter γ (currency mismatch) for which $LR(\gamma)$ is smaller than the flat line (the critical value).

Table 6 reports the percentage of firms which fall into the two regimes each year. It can be seen that the percentage of firms in the "large negative currency mismatch" category ranges from 24 to 41% of the sample over the years. The "moderate currency mismatch" firms range from 76 to 59% of the sample in a given year. It is important to note that there is no upward or downward trend in the number of firms with significant currency mismatch over the years.

[3] Threshold parameter estimation is based on the specification with the full set of control variables; specifications with different set of control variables give pretty similar results.

Table 6 Percentage of firms in each regime by year

Firm class	2003	2004	2005	2006	2007	2008
Currency mismatch ≤ -10.4	40.5	41.9	36.5	24.3	28.4	36.5
Currency mismatch > -10.4	59.5	58.1	63.5	75.7	71.6	63.5
Firm class	2009	2010	2011	2012	2013	2014
Currency mismatch ≤ -10.4	28.4	24.3	29.7	33.8	33.8	29.7
Currency mismatch > -10.4	71.6	75.7	70.3	66.2	66.2	70.3

4.2 Slope parameters estimation

In order to avoid possible endogeneity, I consider a lag in the firm control variables (dollar debt, cash flow, working capital, firm size, leverage, net export, and sales growth). I also consider a lag in the macroeconomic variables of terms of trade, dollarization ratio, and domestic interest rate.

In a first specification, the model is estimated without control variables; then, as a robustness check, in a second specification, the model is estimated adding firm control variables; and finally, the model is estimated by also adding macroeconomic control variables. In all the cases, the threshold parameter estimate is the same, since it is found in threshold models that the threshold parameter estimate is asymptotically independent of the slope parameters.

First, I estimate the conventional linear model in Eq. (3), where there are no threshold effects. Table 7 shows the least squares (LS) coefficient estimates of three specifications (columns 1, 2 and 3). The coefficient of the interaction between dollar debt and the real exchange rate—or, in other words, the coefficient that indicates the balance sheet effect —is practically zero and not significant in all three linear specifications as shown in Table 7. This result is found in many studies: for Latin American firms, see Bleakley and Cowan (2008) and for Peruvian firms, see Carrera (2016).

Second, I estimate the threshold model in Eq. (4), where there is one threshold that determines two regimes. Table 7 shows the estimation results of Eq. (4). The coefficients of primary interest are those that express the interaction between dollar debt and real exchange rate. In all the three specifications (columns 4, 5 and 6), the point estimates suggest that for non-financial firms under the "large negative currency mismatch," the interaction has a negative and significant effect (the parameter estimate is different from zero at the 5% significance level) on a firm's investment; meanwhile, for firms under the "moderate currency mismatch," the interaction has a positive, though not significant, effect on a firm's investment. Thus, the balance sheet effect is observed only for firms that fall into the regime of "large negative currency mismatch;" that is, firms with a currency mismatch lower than – 10.4%.[4]

[4] It is worth mentioning that the results are robust if the following are factored in: total debt instead of leverage, US dollar interest rate instead of domestic interest rate, and different combinations of control variables.

Table 7 Estimation results—dependent variable: investment

Explanatory variables	Linear models			Threshold models		
	(1)	(2)	(3)	(4)	(5)	(6)
Dollar debt × real exchange rate	0.0004	0.0004	0.0000	–	–	–
	(0.0013)	(0.0013)	(0.0013)			
Dollar debt × real exchange rate	–	–	–	− 0.0035	− 0.0037	− 0.0042
(If currency mismatch ≤ -10.4)				(0.0018)	(0.0018)	(0.0018)
Dollar debt × real exchange rate	–	–	–	0.0023	0.0023	0.0020
(If currency mismatch > − 10.4)				(0.0015)	(0.0014)	(0.0014)
Real exchange rate	− 0.1148	− 0.1336	− 0.0649	− 0.1257	− 0.1122	− 0.0414
	(0.0805)	(0.0806)	(0.0827)	(0.0801)	(0.0802)	(0.0822)
Net export × real exchange rate	0.0008	0.0007	0.0005	− 0.0009	− 0.0010	− 0.0012
	(0.0017)	(0.0017)	(0.0017)	(0.0017)	(0.0017)	(0.0017)
Cash flow	–	0.0373	0.0396	–	0.0358	0.0381
		(0.0193)	(0.0193)		(0.0192)	(0.0191)
Working capital	–	0.0251	0.0149	–	0.0289	0.0183
		(0.0152)	(0.0156)		(0.0151)	(0.0155)
Firm size	–	− 0.6558	− 1.5085	–	− 0.5895	− 1.4601
		(0.3963)	(0.5054)		(0.3837)	(0.5013)
Leverage	–	− 0.0008	− 0.0003	–	− 0.0013	− 0.0009
		(0.0032)	(0.0032)		(0.0032)	(0.0032)
Sales growth	–	0.0045	0.0043	–	0.0046	0.0043
		(0.0017)	(0.0017)		(0.0017)	(0.0016)

Table 7 continued

Explanatory variables	Linear models			Threshold models		
	(1)	(2)	(3)	(4)	(5)	(6)
Terms of trade	–	–	0.0305	–	–	0.0313
			(0.0145)			(0.0144)
Dollarization ratio	–	–	−0.0468	–	–	−0.0487
			(0.0173)			(0.0172)
Domestic interest rate	–	–	−0.0134	–	–	−0.0072
			(0.0784)			(0.0778)
Test for threshold effects (p-value)	–	–	–	0.0900	0.0733	0.0667

Standard errors are in parentheses. The test shows the probability value for the null hypothesis of $\widehat{\theta}_1 = \widehat{\theta}_2$

To determine threshold effects, Model (4) was estimated using least squares, allowing for zero and one threshold. The bootstrap p-values (300 bootstrap replications) of the test statistics for different model specifications are shown in Table 7. There is evidence for threshold effects in all specifications, since the bootstrap p-values are lower than 10%.

4.3 Including dynamics

While models (3) and (4) are static panel data models, most economic models also exhibit dynamics; lagged investment captures the accelerator effect of investment, whereby past investments have a positive effect on future investments (Aivazian et al. 2005). The methodology developed by Hansen (1999) allows threshold models to be estimated only in the context of static models. However, the threshold currency mismatch estimated as -10.4 can be fixed, and thus I can estimate models (3) and (4) via maximum likelihood following the procedure developed by Hsiao et al. (2002); this approach has the advantage of not requiring instruments and has a lower bias than the traditional generalized method of moments approach.

The previous techniques cannot be used in the dynamic models, because any transformation to eliminate the individual fixed-specific effect introduces a correlation between the transformed regressors and the transformed error term in the model. In this context, Hsiao et al. (2002) propose a maximum likelihood approach to estimate dynamic panel data models. Thus, the dynamic version of the linear Model (14) and the threshold Model (5) are given by

$$I_{it} = \alpha_i + \beta I_{it-1} + \theta_1 d_{it} + u_{it}. \tag{17}$$

$$I_{it} = \alpha_i + \beta I_{it-1} + \theta' d_{it}(\widehat{\gamma}) + u_{it}. \tag{18}$$

Estimation

In this section, I summarize the maximum likelihood estimation methodology (MLE) only for Model (18), since Model (17) is a specific case of (18) (when $\theta_1 = \theta_2$). The method requires assumption that the error term is independent and identically normally distributed with mean 0 and variance σ_u^2. Hsiao et al. (2002) take the first difference in order to eliminate the individual-specific effect in Model (18), so the model becomes

$$\Delta I_{it} = \beta \Delta I_{it-1} + \theta' \Delta d_{it}(\widehat{\gamma}) + \Delta u_{it}, \tag{19}$$

where $\Delta I_{it} \equiv I_{it} - I_{it-1}$, $\Delta u_{it} \equiv u_{it} - u_{it-1}$ and

$$\Delta d_{it}(\widehat{\gamma}) \equiv \begin{bmatrix} (D^*_{it-1} \times q_t)1(CM_{it} \leq -10.4) - (D^*_{it-2} \times q_{t-1})1(CM_{it-1} \leq -10.4) \\ (D^*_{it-1} \times q_t)1(CM_{it} > -10.4) - (D^*_{it-2} \times q_{t-1})1(CM_{it-1} > -10.4) \end{bmatrix}.$$

When the time period is fixed, or the panel covers only a short period, the MLE of the dynamic panel linear model depends on the initial condition, and the assumption on the initial condition plays a crucial role in devising consistent estimates. Hsiao et al. (2002) assume the process has started from a finite period in the past, such that $\Delta I_{i1} = \delta + \upsilon_{i1}$, where the auxiliary external parameter, δ, is treated as a free parameter, so it does not depend on the model parameters.

Let $\Delta I_i = (\Delta I_{i1}, \Delta I_{i2}, ..., \Delta I_{iT})'$ and $\Delta u_i = (\upsilon_{i1}, \Delta u_{i2}, ..., \Delta u_{iT})'$. Hsiao et al. (2002) show that the Jacobian of the transformation from Δu_i to ΔI_i is unity and the joint probability distribution function of ΔI_i and Δu_i are therefore the same. The covariance matrix of Δu_i has the form

$$\Omega = \sigma_u^2 \begin{bmatrix} \omega & -1 & 0 & \dots & 0 \\ -1 & 2 & -1 & & \\ 0 & -1 & 2 & & \\ \vdots & & & \ddots & -1 \\ 0 & & & -1 & 2 \end{bmatrix}, \tag{20}$$

where $\omega = \sigma_\upsilon^2/\sigma_u^2$.

Let $\theta_\delta = (\delta, \beta, \theta')'$ and define the matrix $\Delta I_{i,-1}$ as follows

$$\Delta I_{i,-1}(\widehat{\gamma}) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \Delta I_{i1} & \Delta d_{i2}(\widehat{\gamma}) \\ 0 & \Delta I_{i2} & \Delta d_{i3}(\widehat{\gamma}) \\ \vdots & \vdots & \vdots \\ 0 & \Delta I_{iT-1} & \Delta d_{iT}(\widehat{\gamma}) \end{bmatrix}.$$

Under the assumption that u_{it} is independent normal, the joint probability distribution function of ΔI_i is given

$$\begin{aligned} \ln L(\theta_\delta, \sigma_u^2, \omega) = & -\frac{nT}{2}\ln(2\pi) - \frac{n}{2}\ln|\Omega(\gamma)| \\ & -\frac{1}{2}\sum_{i=1}^{n}[(\Delta I_i - \Delta I_{i,-1}(\widehat{\gamma})\theta_\delta)'\Omega^{-1}(\Delta I_i - \Delta I_{i,-1}(\widehat{\gamma})\theta_\delta)]. \end{aligned} \tag{21}$$

The likelihood function (21) is well defined, depends on a fixed number of parameters. Then, the MLE $\widehat{\delta}$, $\widehat{\beta}$, $\widehat{\theta}$, $\widehat{\sigma}_u^2$, and $\widehat{\omega}$ are the values that globally maximize $\ln L(\delta, \beta, \theta, \sigma_u^2, \omega)$. For further details on the estimation see Hsiao et al. (2002).

Results

Table 8 shows the dynamic estimation of models (3) and (4) for different specifications, models that include the lagged dependent variable as a regressor. In both models and all specifications, the coefficient of the lagged dependent variable is strongly significant. In the dynamic version of Model (3), the estimated coefficient of the interaction between US dollar debt and real exchange rate is not significant. In the dynamic version of Model (4), the estimated coefficient is negative and significant for firms with a currency mismatch lower than -10.4, similar to the results of static models in Table 7.

As regards other firms' determinants of investment, all estimated models generally reveal: a positive effect of cash flow, which indicates that this constitutes an important source of internal funds for Peruvian firms' investment; a positive effect of sales growth, indicating that the increase in demand represents greater availability of funds for investment spending; and a negative effect of firm size, which shows that smaller Peruvian firms invest more. This latter result is due to the convergence and the financial development experienced by the Peruvian economy and its removal of constraints on small firms; similar results were found for US firms (Gala and Julio 2016). Finally, other firm variables have no effects on investment.

Terms of trade has a positive effect, revealing the importance of international commodity prices on a firm's exports and thus on a firm's investment. Domestic (Peruvian sol) interest rate has the expected negative sign, but it is not significant. The dollarization ratio has a negative effect on a firm's investment, indicating the leading role of the Central Bank of Peru in reducing aggregate dollarization and thus uncertainty and risk, allowing firms to invest more.[5]

Table 8 also shows the negative log-likelihood as a measure of fit of the models; lower values indicate that the model fits the data better. To see if the threshold model statistically fits the data better than the linear model, the null hypothesis being tested is when the linear model is true against the alternative threshold model. Thus, both models can be compared by constructing a likelihood ratio test given by LRT = $-$ 2(log-likelihood (linear model) $-$ log-likelihood (threshold model)). Asymptotically, the test statistic is distributed as a chi-squared random variable, with degrees of freedom equal to the difference in the number of parameters between the two models.

The linear model presented in column 3 has one less parameter than the threshold model in column 6 of Table 8. Then, the test statistic is distributed as a chi-squared with 1 degree of freedom. The value of the likelihood ratio test is 9.4 and lies in the rejection region at 1% of the significance level, so the null hypothesis that the model is linear is rejected in favor of the alternative threshold model. Comparisons between other linear and threshold model specifications in Table 8 lead to the same conclusion.

5 Conclusion

The Peruvian economy may be affected by the balance sheet effect, since a significant portion of the debt held by firms is denominated in US dollars. Thus, in this paper, I identify the balance sheet effect for a sample of 74 non-financial firms during the period 2002-2014. To this end, I estimate a panel data threshold model, and find that such effects depend on the specific currency mismatch regime.

Using different specifications with different sets of control variables, I find significant balance sheet effects for firms with a currency mismatch below than -10.4%,

[5] The significant effects are at the 5% significance level.

Table 8 Estimation results—dependent variable: investment

Explanatory variables	Linear models			Threshold models		
	(1)	(2)	(3)	(4)	(5)	(6)
Dollar debt × real exchange rate	0.0009	0.0006	0.0004	–	–	–
	(0.0012)	(0.0012)	(0.0012)			
Dollar debt × real exchange rate	–	–	–	− 0.0029	− 0.0025	− 0.0025
(If currency mismatch $\leq$ -10.4)				(0.0010)	(0.0010)	(0.0010)
Dollar debt × real exchange rate	–	–	–	0.0006	0.0007	0.0008
(If currency mismatch > -10.4)				(0.0008)	(0.0008)	(0.0008)
Real exchange rate	− 0.1309	− 0.0936	− 0.0418	− 0.0526	− 0.0408	0.0001
	(0.0719)	(0.0679)	(0.0687)	(0.0555)	(0.0525)	(0.0543)
Net export × real exchange rate	0.0000	0.0001	− 0.0001	− 0.0008	− 0.0008	− 0.0010
	(0.0015)	(0.0014)	(0.0014)	(0.0015)	(0.0014)	(0.0014)
Lagged dependent variable	0.3746	0.2680	0.2741	0.3726	0.2659	0.2711
	(0.0318)	(0.0325)	(0.0327)	(0.0315)	(0.0322)	(0.0324)
Cash flow	–	0.0457	0.0462	–	0.0460	0.0466
		(0.0174)	(0.0173)		(0.0173)	(0.0172)
Working capital	–	0.0241	0.0176	–	0.0230	0.0155
		(0.0133)	(0.0136)		(0.0133)	(0.0135)
Firm size	–	− 0.5929	− 1.2605	–	− 0.5373	− 1.2374
		(0.3363)	(0.4317)		(0.3368)	(0.4294)
Leverage	–	− 0.0005	0.0000	–	− 0.0004	0.0001
		(0.0029)	(0.0029)		(0.0029)	(0.0029)

Table 8 continued

Explanatory variables	Linear models			Threshold models		
	(1)	(2)	(3)	(4)	(5)	(6)
Sales growth	–	0.0042	0.0040	–	0.0041	0.0039
		(0.0015)	(0.0015)		(0.0015)	(0.0015)
Terms of trade	–	–	0.0441	–	–	0.0431
			(0.0136)			(0.0136)
Dollarization ratio	–	–	−0.0345	–	–	−0.0387
			(0.0157)			(0.0160)
Domestic interest rate	–	–	−0.0560	–	–	−0.0353
			(0.0710)			(0.0725)
Negative log-likelihood	2613.7	2491.5	2483.3	2609.0	2486.9	2478.6

Standard errors are in parentheses

which means that the interaction between US dollar debt and the real exchange rate negatively affects investment decisions.

To improve robustness, dynamics is included in the model, which requires a different estimation method. The results show, across all specifications, that the coefficient of the lagged dependent variable is significant and that the significant balance sheet effects found in the static threshold model hold.

As to the other determinants of a firm's investment, all estimated models generally reveal a positive effect of cash flow and sales growth, and the negative effect of firm size; while other firm variables have no effects. Terms of trade has positive effects, the dollarization ratio has a negative effect, and the domestic (Peruvian sol) interest rate has a nonsignificant effect.

Other variables should be included in the analysis, including derivatives to hedge undesired movements in the exchange rate; information on repurchasing firms that own debt in US dollars by issuing new debt in Peruvian soles; and the term structure of liabilities. However, these variables are not available in the financial information pertaining to Peruvian firms.

Acknowledgements I would like to thank Guillermo Moloche, Renzo Castellares, Diego Winkelried, and the anonymous referee for valuable comments and suggestions. I also thank the participants of the Third Annual Conference of The Bilateral Assistance and Capacity Building for Central Banks Program in Geneva, Switzerland; the XXXIII Meeting of Economists of the Central Bank of Peru in Lima, Peru; the 20th Annual Meeting of the Latin American and Caribbean Economic Association in Santa Cruz, Bolivia; and the 2015 Annual Congress of the Peruvian Economic Association in Lima, Peru. I am grateful to Bryce Cruz, Yamily León, Nevenka Ciriaco and Andrea Vilchez for providing excellent research assistance. Special thanks to Patricia Paskov for kindly review the paper. All remaining errors are mine.

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