Tsoukalas, J., Tsoukas, S. and Guariglia, A. (2017) To what extent are savings-cash flow sensitivities informative to test for capital market imperfections? *Review of Finance*, 21(3), pp. 1251-1285. (doi:10.1093/rof/rfw043)

# To what extent are savings–cash flow sensitivities informative to test for capital market imperfections?*

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This version: April 2016

## Abstract

We construct a simple model with lumpy investment, cash accumulation and costly external finance. Based on this model, we propose a new savings specification aimed at examining savings behavior in the presence of investment lumpiness and financial constraints. We then test a key prediction of our model, namely, that under costly external finance, savings-cash flow sensitivities vary significantly by investment regime. We make use of a panel of firms from transition and developed economies to estimate the new savings regression which controls for investment spikes and periods of inactivity. Our findings confirm the validity of the model's prediction.

*Keywords:* Investment, fixed capital adjustment costs, cash flow, capital market imperfections.

*JEL Classification:* D21; E22; E32; G31.

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[*] We thank two anonymous referees, Michael Bleaney, Murillo Campello, Igor Cunha, Dirk Hackbarth, our discussant at the 2014 European Finance Association, and George Hall, our discussant at the 2011 American Economic Association Meeting, for helpful comments and suggestions. We also thank participants to the 2014 European Finance Association, the 2011 American Economic Association Meeting, the 2010 European Economic Association Conference, the 2010 Royal Economic Society Conference and seminar participants at the University of Essex, Queen Mary University of London and the University of Sheffield. Serafeim Tsoukas gratefully acknowledges support from the Economic and Social Research Council, grant PTA-026- 27-1790. Any remaining errors are our own.

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# 1 Introduction

Examining and testing whether capital market imperfections affect firm behavior has been in the financial economics agenda at least since the seminal contribution of Fazzari et al. (1988), who provide evidence that financial constraints matter for corporate investment (see Schiantarelli (1995); Hubbard (1998); and Bond and Reenen (2006), for surveys). Following this study, investment–cash flow sensitivities have been a popular metric for gauging the importance of financial constraints. Recently, partly due to critiques regarding the validity of these sensitivities as an informative indicator of financial constraints, a number of authors have suggested an alternative framework, in order to identify financial constraints.[1] Among these, Almeida et al. (2004) propose to examine the *cash flow sensitivity of cash*.[2] Their simple idea is that firms with investment opportunities but limited or no access to external capital markets (constrained firms) will save cash out of cash flow when they anticipate to need resources for future investment expenditures. By contrast, unconstrained firms will not engage in such liquidity management since they can easily acquire external finance when the need arises.

Based on empirical tests using a savings–cash flow regression framework and data from the U.S. and other G-7 countries, Almeida et al. (2004) and, subsequently, Khurana et al. (2006) provide evidence, that confirms the prediction above: constrained firms exhibit a positive sensitivity of cash to cash flow, while unconstrained firms exhibit no systematic sensitivity. The authors interpret these results as more powerful and less ambiguous evidence of financial constraints, relative to results obtained within the investment–cash flow framework. By contrast, in an influential paper, Riddick and Whited (2009) generalize the theoretical analysis in Almeida et al. (2004) and provide

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[1] Critiques raised by Kaplan and Zingales (1997), Cleary (1999), and more recently by Erickson and Whited (2000, 2002, 2012), Gomes (2001), Cooper and Ejarque (2003), Abel and Eberly (2003), Cummins et al. (2006) and Tsoukalas (2011) cast doubt on the validity of investment-cash flow sensitivities as indicators for the presence of capital market imperfections. Broadly speaking these critiques refer to either measurement error in Tobin's $Q$ (which typically controls for investment opportunities) or specification bias associated with the linear investment equation augmented with cash flow.

[2] Hereafter, we will refer to savings and cash accumulation interchangeably.

robust evidence that once measurement error in Tobin's $Q$ is accounted for, the sensitivity of savings to cash flow is negative for the majority of firms from the U.S. and other G-7 countries they examine. They conclude that while the savings–cash flow sensitivity contains information about financial constraints, other confounding factors, render this sensitivity no more informative than the investment–cash flow sensitivity.

Given these apparently conflicting findings our goal in this paper is to derive testable predictions regarding the savings–cash flow sensitivity from a model with lumpy investment, costly external finance, and cash accumulation (similar to the one analyzed in Riddick and Whited (2009)).[3] We then propose a modification to the original Almeida et al. (2004) equation that, while nesting the latter specification, provides a sharper empirical test for our model's predictions. Using the model as a laboratory, we also examine the extent to which the savings–cash flow sensitivity may contain information on the presence of costly external finance.

The intuition for our savings equation is as follows. A stylized version of the model generates two investment regimes: periods during which firms experience low or zero investment in physical capital (investment inaction) and periods during which firms invest substantially (investment spikes). Due to the intermittent nature of investment in the model, firms that face costly external finance use cash to transfer resources from periods of investment inaction to periods of investment spikes, in order to avoid using more costly external funds when they invest during spikes. In other words, firms accumulate cash (or equivalently save) during inaction periods and decumulate cash (or equivalently dissave) during periods of investment spikes. This behavior results from the assumption of costly external finance. In the model, firms invest in large bursts either during periods when productivity is high or when the capital stock has (through depreciation) fallen below a threshold, or both. These bursts are very intense and, due to the presence of the fixed cost when

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[3] Investment lumpiness has been extensively documented in earlier work. Fixed costs make investment spending lumpy, i.e. periods of investment inaction are followed by periods of investment (or dis-investment) bursts (or spikes). Doms and Dunne (1998) and Cooper and Haltiwanger (2006), provide evidence from plant level data which exhibit these features, as a consequence of fixed capital adjustment costs.

investment is non-zero, concentrated in a single period.

At the same time, the presence of investment lumpiness and costly external finance generates a non-linear cash policy. Firms maintain a constant level of cash during periods of inaction (in order to use it when they invest during spikes to avoid the costly external finance), so the policy rule is flat during those periods. When there is an investment spike, firms use some or all of this cash to finance investment (as cash flow is not sufficient to finance these large bursts of activity). Thus, during and immediately after an investment spike, the cash policy is very non-linear: Cash changes from a positive level to either zero or a lower positive level (depending on the size of the spike). Hence, the change in cash, i.e. savings, is negative during the periods immediately before and during the spike. The firm then builds up its cash level to what it was prior to the spike, so the change in cash or savings becomes positive. To summarize, the cash policy follows a step function, i.e, high-low-high-low.

Our model generates therefore periods during which the change in cash switches sign abruptly, while cash flow typically rises: just prior and during a spike (high productivity) and also after a spike (since productivity is persistent and firms have built a lot of capital). In the model, these periods dominate the savings–cash flow correlation. A clear empirical prediction arising from the model is therefore that the savings–cash flow sensitivity will switch sign as firms switch investment regimes. Importantly, the design of the model is such that this behavior is entirely absent for firms that are financially unconstrained, because these firms are impatient (i.e. their discount rate is higher than the market interest rate, and they prefer to distribute profits to the firm's owners). In other words, unconstrained firms will keep zero cash in all times and states.

The new savings equation we propose is based on the mechanics of the model regarding investment spikes and cash accumulation explained above. Specifically, it takes into account the investment regime when estimating the cash flow sensitivity of cash accumulation, and focuses on the sign switch in this sensitivity as firms change investment regimes, rather than on the overall magnitude and sign of the sensitivity as in Almeida et al. (2004) and Riddick and Whited (2009).

Similar to Riddick and Whited (2009), our analysis indicates that the overall sign and magnitude of the sensitivity from the standard specification may not necessarily be informative as a summary measure of financial constraints in the presence of investment lumpiness. Relative to our proposed specification, the overall sensitivity from the standard specification may be affected by parameters that are not related to financial constraints, i.e. parameters related to production and investment technologies. In our simulation exercise, we show that (with a suitable calibration) the overall sensitivity obtained from the standard specification may indicate (incorrectly) the absence of costly external finance. By contrast, our simulation results suggest that the sign switch in the cash flow sensitivity of cash accumulation is remarkably robust to variations in those parameters. Hence compared to the standard Almeida et al. (2004) specification, our proposed specification is in principle equipped to be used as a sharp test for the model's predictions, and our model simulations suggest it may contain information for detecting financial constraints under investment lumpiness. Moreover, it is as simple as the original Almeida et al. (2004) equation to implement. An important caveat of our analysis is in order. The empirical test based on the modified savings equation we propose is not monotonic in the degree of financial constraints and hence it can only suggest the presence, rather than definitively establish, the magnitude and the intensity of financial constraints. In general, parameters that depend on production technologies and other features of the model affect this sensitivity and only structural estimation approaches (such as, for example, the one proposed in Hennessy and Whited (2007)) can hope to accurately identify relative degrees of financial constraints. This goes beyond the scope of this paper.

Of course, the reliability of our conclusions and the validity of the modified equation we propose depend on the information contained in the sample we use to implement our empirical test. The advantage of our approach lies in the fact that we encompass both regimes of investment and thus exploit the entire spectrum of the model's prediction. Our dataset allows to control for differences in investment regimes as it contains such information. We choose a sample that (a) comes from a universe of unlisted small firms (thus likely to face severe financial constraints) and (b) exhibits lumpy investment behavior. Specifically, our sample consists of a panel of 4,181 firms from four transition economies (Bulgaria, the Czech Republic, Poland, and Romania) and 9,210 firms from four developed economies (Belgium, France, Germany and the U.K.). We estimate the modified savings equation that controls for investment regimes and, in line with the predictions of our model, find negative and significant savings–cash flow sensitivities for firms that experience investment spikes and positive and significant savings–cash flow sensitivities for firms that are not in a spike regime.

The rest of the paper proceeds as follows. In section 2, we describe our model. Section 3 presents simulation results, which motivate our empirical analysis. Section 4 describes our dataset and presents some descriptive statistics. Section 5 illustrates our baseline specifications and estimation methodology. Section 6 presents our main empirical results, and section 7 concludes.

# 2 The Model

We model an industry with many heterogenous firms that produce, invest in fixed capital, and save in cash, where cash earns a risk free rate of return. As in Cooper and Haltiwanger (2006), investment is subject to both convex and non-convex adjustment costs. These costs are a combination of quadratic and fixed adjustment costs. External finance is available, but only at a premium over the risk free rate. The following sections describe the set-up of our model.

## 2.1 The firm's problem: Production and investment

Firm $j's$ production function at time $t$ is given by:

$$y_{jt} = s_{jt} k_{jt}^{\alpha}, \qquad 0 < \alpha < 1, \tag{1}$$

where production, $y_{jt}$, depends on capital, $k_{jt}$, and a productivity disturbance, $s_{jt}$. The parameter $\alpha$ determines the share of capital in production. The (log of) the productivity disturbance is assumed to follow an AR(1) process:

$$\ln(s_{jt+1}) = \rho \ln(s_{jt}) + \varepsilon_{jt+1}, \tag{2}$$

where, $\rho$ is the autoregressive parameter, and $\varepsilon_{jt}$ is assumed to be distributed as IID $N(0, \sigma)$, with $\sigma$ denoting the standard deviation.

The firm accumulates capital according to the following rule:

$$k_{jt+1} = (1 - \delta_k)k_{jt} + i_{jt}, \qquad 0 \leq \delta_k \leq 1, \tag{3}$$

where $i_{jt}$ is fixed investment and $\delta_k$ denotes the depreciation rate of capital.

Adjusting the capital stock is assumed to be costly. Specifically, as in Cooper and Haltiwanger (2006), we assume the firm faces both convex and non-convex adjustment costs. The adjustment costs consist of two components: a variable cost component, $c_v(i_t, k_t)$, given by a quadratic form:

$$c_v(i_{jt}, k_{jt}) = \frac{\gamma}{2}\left(\frac{i_{jt}}{k_{jt}}\right)^2 k_{jt}, \qquad \gamma \geq 0. \tag{4}$$

and a non-convex component which is given by:

$$c_f(k_{jt}) = \left\{ \begin{array}{cc} Fk_{jt} & \text{for } i_{jt} \neq 0 \\ 0 & \text{for } i_{jt} = 0 \end{array} \right\}, \qquad F \geq 0, \tag{5}$$

where $F$ denotes a fixed cost incurred by the firm during investment episodes. This component is scaled by the capital stock, $k_{jt}$, to eliminate any size effects.

In addition to the real decisions described above, firms also make a financial decision. Specifically, in each period each firm decides the amount of cash to hold, $b_{jt}$. By definition, this amount is constrained to be non-negative, i.e. firms can only save. Savings earn a positive post-tax risk-free interest rate of $r$. As in Gomes (2001) and Whited (2006), we assume that firms can obtain external funds to finance expenditure but only at a premium over the rate offered on savings. This is a parsimonious and tractable way to introduce costly external finance in the model. Specifically, whenever a firm's expenditure exceeds the available sources of income, the firm pays a premium over the risk-free rate. Formally, let

$$\omega_{jt} = s_{jt}k_{jt}^{\alpha} - k_{jt+1} + (1-\delta_k)k_{jt} - Fk_{jt} - \frac{\gamma}{2}\frac{(k_{jt+1} - (1-\delta_k)k_{jt})^2}{k_{jt}} + (1+r)b_{jt} - b_{jt+1} \quad (6)$$

denote the firm's net cash flow or dividend. We assume the firm pays a cost of obtaining external finance given by a function, $\varphi_t(\bullet)$, such that, $\varphi_t(\bullet) > 0$ if $\omega_{jt} < 0$, and $\varphi_t(\bullet) = 0$ otherwise. To make this operational we assume it takes the following form:

$$\begin{aligned}\varphi(-\omega_{jt}) =& \lambda(-\omega_{jt}) = \lambda\big(k_{jt+1} - (1-\delta_k)k_{jt} - s_{jt}k_{jt}^{\alpha} \\ &+ Fk_{jt} + \frac{\gamma}{2}\frac{(k_{jt+1} - (1-\delta_k)k_{jt})^2}{k_{jt}} - (1+r)b_{jt} + b_{jt+1}\big)\end{aligned} \quad (7)$$

In the expression above, $\lambda$ is a parameter capturing the premium the firm pays above the risk-free rate in order to use external funds. Notice that the expression in the external finance cost function is simply expenditures minus internal sources of funds. This cost is assumed to be linear. Also note that other things being equal, a higher level of cash, $b_{jt}$, helps to reduce the cost of external finance.

Given the structure of the problem above, the firm will find itself in either of two investment regimes: a regime where it invests heavily, and a regime where investment is low (e.g. to cover depreciation) or zero.[4] Let the value function describing each regime be given by $V^{a}(s_t, k_t, b_t)$

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[4] With both quadratic and fixed adjustment costs, firms with a small capital stock may, conditional on productivity,

and $V^i(s_t, k_t, b_t)$ for the active and the inactive regime, respectively (dropping the subscript $j$ for convenience). The firm then solves the following problem:

$$V(s_t, k_t, b_t) = \max\{V^a(s_t, k_t, b_t), V^i(s_t, k_t, b_t)\} \tag{8}$$

The value functions for the active and inactive regimes are given respectively by:

$$\begin{aligned} V^a(s_t, k_t, b_t) =& s_t k_t^\alpha - k_{t+1} + (1 - \delta_k)k_t - \frac{\gamma}{2}\frac{(k_{t+1} - (1 - \delta_k)k_t)^2}{k_t} \\ & - Fk_t + (1 + r)b_t - b_{t+1} - \varphi_t(\bullet) + \beta E_{s_{t+1}|s_t} V(s_{t+1}, k_{t+1}, b_{t+1}), \end{aligned} \tag{9}$$

and

$$V^i(s_t, k_t, b_t) = s_t k_t^\alpha - \varphi_t(\bullet) + (1 + r)b_t - b_{t+1} + \beta E_{s_{t+1}|s_t} V(s_{t+1}, k_t(1 - \delta_k), b_{t+1})). \tag{10}$$

In the value function formulation above, $\beta$ denotes the discount factor and $E$, the expectation operator. One particular and important feature of the solution concerns the behavior of cash, $b_t$. In the simulation exercise described below, we assume that $\beta(1 + r) < 1$ so that absent any cost of obtaining external funds, the firm will never hold positive cash balances (equivalently, it will always distribute profits to owners). In fact, cash balances will always be set equal to zero in this case. If however, there is a premium for using external funds—as captured by the $\varphi(\bullet)$ function—, then the firm will find it optimal to save in order to reduce or eliminate the future external finance cost when investing. We will return to this point below.

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choose a low investment level, rather than an investment spike. This is because, the quadratic costs penalize the firm for making large adjustments, while fixed costs penalize the firm for making small and frequent investments. Appendix A fleshes out the intuition behind the model in more detail.

## 2.2 Solution and calibration

We solve the dynamic programming problem above using value function iteration. The model is parameterized assuming the time period is one year. The details of the solution and the calibration of model parameters are described in Appendix A. The outcome of this exercise are policy functions for investment and cash. These policy functions are given by, $I_t = I(k_t, b_t, s_t)$, and $b_{t+1} = b(k_t, b_t, s_t)$, respectively. We use the policy functions to simulate panels that are broadly in line with the characteristics of our data sample (see Appendix A, and Section 4).[5]

It is useful to briefly comment on the policy functions. First, given the fixed cost of adjustment, investment displays a non-monotonic relationship with respect to capital. It is well known that with fixed costs of adjustment, the optimal investment policy entails periods of inactivity followed by periods of strong positive investment activity or investment spikes. For example, the firm will adjust its capital stock upward, either when it is hit by a sufficiently high and persistent productivity shock, or when the capital stock declines below a critical level and the productivity of capital becomes very high. This is the well known (S,s) adjustment rule as illustrated in Abel and Eberly (1996), Caballero and Engel (1999), and others. However, the presence of quadratic adjustment costs also implies that, conditional on productivity, firms may choose a low investment rate because these costs penalize large adjustments in capital.

The important characteristic of the solution that we will exploit in the empirical section below concerns the behavior of cash. Under *costless* external finance, the firm sets cash balances equal to zero (at all times and states), as it discounts the future more heavily compared to the return earned on cash (recall the assumption $\beta(1 + r) < 1$). However, this changes when there is a premium on external funds as captured by the external finance cost, $\varphi(\bullet)$.

The presence of investment lumpiness and costly external finance generates a non-linear cash policy. Firms will maintain a constant level of cash during periods of inactivity or low activity

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[5] The model we use is quite stylized. Its value lies in illustrating the main forces behind investment and cash accumulation, rather than in providing a complete and accurate description of investment behavior in our sample of firms.

(e.g. replacement investment), in order to use it when they invest during a spike, to avoid the costly external finance. Thus the cash policy rule is flat during those periods. When there is an investment spike, firms use some or all of this cash to finance investment, as cash flow is not sufficient for these large bursts of activity, and they are very reluctant to use costly external finance. Thus, before, during and immediately after an investment spike, the cash policy is very non-linear. Cash changes from a positive level to either zero or a lower positive level (depending on the size of the spike). So, the change in cash, i.e. savings, during these periods (immediately before and during the spike) is negative. The firm then builds up its cash level to what it was prior to the spike, so the change in cash or savings becomes positive. To summarize, the cash policy follows a step function, i.e. high-low-high-low. The firm will accumulate cash in periods of investment inactivity or periods of low investment, where cash flow is more than enough to finance this low level of investment. It will then use the accumulated cash to finance spikes of investment activity when it finds it optimal to do so. This behavior is a direct consequence of the firm's incentive to minimize the need to use external funds when investing. Consequently, the sensitivity of savings to cash flow will vary according to the investment regime the firm is operating in. The sensitivity will be positive in periods of inactivity as the firm builds up cash balances in anticipation of future spikes, and negative in periods of investment spikes as the firm uses the accumulated cash to invest while cash flow is rising due to the high productivity of capital.[6] Figure 1 in Appendix A illustrates these features of the solution using a very simple version of the model. This is the key feature of the solution we exploit in Section 5.

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[6] In the model simulations discussed in Section 3, firms may at times find it optimal to invest at a low rate (e.g. replacement investment). In this case, they may still accumulate cash in anticipation of a future investment spike, provided their cash flow is sufficient to finance this low investment level.

# 3 Simulation results

We use the policy functions obtained in the previous section in order to generate samples of firms that differ according to (a) the history of idiosyncratic shocks they face and (b) their initial size (as measured by the capital stock). We simulate two industries each consisting of 25,000 firm-year observations. One industry faces a premium for external funds (as specified in equation (7)), while the other does not. We use the two simulated panels to test whether the empirical equation we propose can reliably identify the firms that face costly external finance.

## 3.1 Savings specification under lumpiness

Since the sensitivity of savings to cash flow crucially depends on the investment regime as explained above, we estimate the following equation:

$$\frac{\Delta b_{it+1}}{b_{it}+k_{it}} = \beta_0 + \beta_1 \frac{\text{sales growth}_{it}}{b_{it}+k_{it}} + \beta_2 \frac{CashFlow_{it}}{b_{it}+k_{it}} * SPIKE_{it} + \beta_3 \frac{CashFlow_{it}}{b_{it}+k_{it}} * (1 - SPIKE_{it}) + \beta_4 (b_{it}+k_{it}) + \epsilon_{it} \tag{11}$$

In the equation above, $\Delta$ is the first difference operator and $SPIKE_{it}$ is a dummy variable that controls for the investment regime. Specifically, it takes the value of one for observations with investment spikes and zero for all other observations. We define an investment spike when the investment rate exceeds $50\%$. We will also use this distinction in the empirical section below in order to sharpen our empirical test and link it precisely with our theoretical model. In the equation above, we use sales growth as a measure of investment opportunities, for consistency with the empirical work (our firms are unlisted).[7] Sales growth for firm $j$ is defined as the growth in $s_{jt}k_{jt}^{\alpha}$.

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[7] For robustness, in all our simulation results, we have also used Tobin's $Q$ (computed from the model simulations), defined as the value of the firm over its capital stock, instead of sales growth as a right hand side variable. The

Also note that the equation above is a modified version of the empirical equation in Almeida et al. (2004), the only difference being the $SPIKE_{it}$ dummy.

The top panel of Table 1 reports estimation results from equation (11). As predicted by the model, firms in the non-spike regime exhibit positive savings-cash flow sensitivities, while firms who experience spikes exhibit negative savings-cash flow sensitivities. Thus a defining characteristic of the specification is that it clearly shows the sign switch in the cash flow sensitivity of savings predicted by the model. The results from this regression clearly illustrate the ability of the savings regression to detect the presence of costly external finance in the simulated panels. This can be seen by comparing the savings cash flow sensitivities in columns 1 and 2 in the top panel of Table 1. These sensitivities are statistically different from zero (either positive or negative depending on the investment regime) in the industry with costly external finance, but identically equal to zero in the industry without costly external finance. The intuition for this follows directly from the solution of the model with and without costly external finance. In the industry with costly external finance, savings are accumulated during non-spike periods, and run down during spike periods. By contrast, in the industry without costly external finance, savings are equal to zero at all times and states, so the coefficients on the right hand side variables are identically equal to zero.

It is interesting to compare the results above with results obtained from a specification that ignores the distinction of investment regimes,

$$\frac{\Delta b_{it+1}}{b_{it}+k_{it}} = \beta_0 + \beta_1 \frac{\text{sales growth}_{it}}{b_{it}+k_{it}} + \beta_2 \frac{CashFlow_{it}}{b_{it}+k_{it}} + \beta_3 (b_{it}+k_{it}) + \epsilon_{it} \tag{12}$$

The savings regression above comes directly from Almeida et al. (2004) and was subsequently used by Khurana et al. (2006) and Riddick and Whited (2009). The bottom panel of Table 1 reports the estimates from this specification. Because in the simulation, there is a higher fraction of observations that are inactive (exhibiting a positive sensitivity, approximately 65% of the sample)

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regression results from this specification were qualitatively similar to those presented in Table 1 and are not reported for brevity but are available upon request.

compared to firms that exhibit investment spikes (exhibiting a negative sensitivity, approximately 35% of the sample), the average sensitivity is positive in the industry with costly external finance. By contrast, in the model without costly external finance, savings, and consequently the savings-cash flow sensitivities, are zero in all periods. A notable finding which adds to the credibility of our proposed equation (11), is the significant increase in $\overline{R}^2$ between the specification that ignores investment regimes (0.06) and the specification that controls for them (0.43). This suggests the dummy variable $SPIKE_{it}$ captures to a great extent the non-linearity in the savings policy function and improves the fit of the equation. Yet, given that, in this model environment, the conventional specification seems to be successful in detecting the presence of costly external finance, what makes our proposed specification more suitable when testing for the presence of costly external finance? This point can be illustrated by looking at alternative model parameterizations.

## 3.2 Alternative model parameterizations

We now examine the robustness of the theoretical predictions regarding the sign switch in the cash flow sensitivity of cash accumulation under different parameterizations of the model. This exercise confirms that the conventional specification is misspecified and, importantly, may lead to incorrect conclusions regarding the existence of financial constraints. In this section we focus on the parameters that control for adjustment costs, the depreciation rate, and on those that control for the volatility and persistence of the productivity process. An extensive sensitivity analysis of the key prediction to all model parameters is reported in Appendix A (Tables A.3 to A.8). It is shown that the sign switch in the cash flow sensitivity of cash accumulation is remarkably robust to variation in a sensible range of model parameters.

The top panel of Table 2 reports estimation results from equation (11), while the bottom panel reports estimation results from the standard specification, equation (12). The Table reports results from four different parameterizations of the model, each described in the relevant column, including the baseline calibration. As predicted by the model, under all different parameterizations, firms that do not experience spikes (i.e. whose investment rates are always below 50%) exhibit positive savings-cash flow sensitivities, while firms who experience spikes (i.e. investment rates above 50%) exhibit negative savings-cash flow sensitivities. In the column labelled 'Perturbation I', increasing the depreciation rate increases the fraction of observations where firms undertake positive investment. The estimated cash flow coefficient interacted with the $SPIKE$ dummy are in line with the predictions of the model, namely negative during investment spikes and positive otherwise. The bottom panel in the same column shows that the overall sensitivity is negative, which echoes the result in Riddick and Whited (2009), but also suggests that the sign of the overall sensitivity does not provide information regarding the existence of costly external finance. The column labelled 'Perturbation II' reports results from a simulated panel where the fixed cost and convex cost adjustment parameters are both reduced to 0.01 and the depreciation rate is set at 0.25, while the parameters associated with the productivity process are as in the column labelled 'Perturbation I'. The column labelled 'Perturbation III' reports results from a simulated panel where the fixed cost and convex cost adjustment parameters are both reduced to 0.01 and all other parameters are as in the baseline. In both cases, the estimated cash flow coefficients interacted with the $SPIKE$ dummy are again in line with the predictions of the model. Regardless of the perturbation, our proposed empirical specification exhibits the sign switch.

In the column labelled 'Perturbation IV', the depreciation parameter is increased to 0.25. The interesting finding with this calibration is that the conventional specification (without the $SPIKE$ dummy) shows an insignificantly different from zero cash flow sensitivity of cash accumulation (bottom panel). This suggests that a researcher who ignores the lumpiness factor will erroneously conclude that this panel of firms is not subject to costly external finance. Even though the firms in the sample are subject to costly external finance, the standard specification cannot detect it. In other words, if the null hypothesis is the presence of financial constraints, there is a significant type I error in this regression. By contrast, as shown by the top panel, the specification that controls for investment lumpiness correctly predicts a negative sensitivity during investment spikes and a positive sensitivity otherwise, i.e. the sign switch, indicative of costly external finance.

Overall, the results reported in Tables 1 and 2, clearly suggest the ability of the proposed savings specification to detect the presence of costly external finance in the simulated panels.

# 4 Data, summary statistics, and investment distributions

## 4.1 Data and summary statistics

Our data set is drawn from the annual accounting reports taken from the AMADEUS database, published by Bureau Van Dijk Electronic Publishing (BvDEP). The database includes balance sheet and profit and loss information for over 11 million public and private companies in 41 European countries over the period 1998-2005.[8] Our focus is on four transition economies, namely, Bulgaria, the Czech Republic, Poland and Romania (also studied by Konings et al. (2003)) and four developed economies, namely, Belgium, France, Germany and the U.K. (studied by Bond et al. (2003) who focus on investment–cash flow sensitivities). The sample we choose to work with is particularly well suited for evaluating the validity of the model predictions and consequently the suitability of our proposed empirical specification as a test for the sign switch in the presence of costly external finance, as it provides information on unlisted companies which are particularly likely to face costly external finance and/or financing constraints (Guariglia (2008)).[9] The importance of investment lumpiness, a key consideration for testing our proposed specification, is documented below in section 4.2.

We drop observations with negative sales, as well as observations with negative total assets. Firms that do not have complete records on our main regression variables are also dropped. To control for the potential influence of outliers, we exclude observations in the one percent tails of

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[8] To be included in Amadeus, companies must satisfy at least one of the following criteria: i) turnover greater than 15 million EUR; ii) number of employees greater than 150; iii) total assets greater than 30 million EUR. In addition to financial information, Amadeus also assigns companies a four-digit NACE Rev. 1 code which we use to classify firms and construct industry dummy variables. Our sample is limited to firms that operate in the manufacturing industry.

[9] In particular, according to our data 99.9% of the firms in the sample are not publicly quoted.

each of our regression variables. Finally, we drop all firms with less than 5 years of consecutive observations. Our final panel, which is unbalanced, covers 459 firms for Bulgaria (corresponding to 2250 observations), 1515 firms for the Czech Republic (corresponding to 7479 observations), 1201 firms for Poland (corresponding to 5428 observations), 1006 firms for Romania (corresponding to 4513 observations), 1536 firms for Belgium (corresponding to 8475 observations), 4133 firms for France (corresponding to 21574 observations), 842 firms for Germany (corresponding to 3204 observations), and 2699 firms for the U.K. (corresponding to 10214 observations). Table 3 reports summary statistics. Definitions of all variables are provided in Appendix A. The cash to assets ratio ranges from 5.8% in Romania to 7% in the Czech Republic, and from 5.9% in Germany to 9.1% in Belgium. These numbers are lower than those reported by Almeida et al. (2004) for US firms, which range from 8-9% for unconstrained firms to 15% for their constrained counterparts, but are in line with those reported by Kalcheva and Lins (2007) for countries such as Spain and Portugal. Finally, the cash accumulation to assets ratios range from approximately 0.1% for Romania to 0.9% for Bulgaria, and vary between 0.2% and 0.6% in the four developed economies. Investment rates in all eight countries are quite high on average, ranging from around 17% in Romania to 35% in Belgium, and there is significant variation around the mean as evidenced from the standard deviations.

## 4.2 Investment distributions: evidence for lumpiness

In this section we describe some features of firm investment rates in our dataset. Figure 1 shows the investment rates' distributions for each country. On immediate inspection, the distributions appear to be non-normal. There is in fact a considerable mass around zero, fat tails and some right skewness.[10] We summarize the main features of these distributions in Table 4. First, there is investment inaction: firm-year observations with investment rates near zero (less than 2% in

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[10] The skewness and kyrtosis statistics strongly indicate right skewness and a right fat tail in all countries, thus supporting the non-normality of the investment rate distributions. In all cases, we reject—at the 1% significance level—the null hypothesis of normality.

absolute value) range from around 5% in Poland and Romania to 11.4% in Bulgaria in the set of transition economies, while they are slightly smaller in the set of developed countries, varying between 6.3% in the U.K. to 2.6% in Germany.[11]

These periods of inaction are complemented by periods of investment spikes. Since there is not a unique acceptable criterion, we look at various thresholds in order to define an investment spike. For an investment episode to be defined as a spike we require it to be occurring rather infrequently, while at the same time to account for a significant portion of total investment spending. In the baseline, we define an investment spike when the investment rate exceeds 50%. This threshold ranges from approximately twice to three times the average investment rate in our sample. Investment rates exceeding 50% account for a considerable fraction of firm-year observations in the transition economies group, ranging from approximately 14% for the Czech Republic to 23% for Bulgaria. In the set of developed economies, they account for approximately 17% in the U.K. to 23.4% in Belgium. Importantly, investment spikes account for a *considerable fraction* of total investment spending. As can be seen from Table 4, the average fraction of investment spikes in total investment (measured by the 50% threshold) ranges from 32% in the Czech Republic to 89% in Romania, and from 31% in Germany to 61% in the U.K.

We also report an alternative measure of investment lumpiness based on the percentage of firm-year observations characterized by investment rates at least 2.5 times above the firm-level median investment rate for each country. Using this criterion, a considerable fraction of firm-year observations experience an investment spike. The fractions range, for example, from 8.4% in Poland to 36.6% in Romania in the set of transition economies, and from 12.6% in Belgium to 51.7% in Germany in the developed economies group. Taken together, these observations strongly suggest investment rates in our dataset are characterized by significant asymmetries and lumpiness that suggest the presence of fixed capital adjustment costs.[12]

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[11] We define investment inaction as investment rates less than 2 percent in absolute value. There are few identically zero investment rates in our sample given that we have firm-level data and aggregation across plants and heterogeneous capital goods is always likely to generate a small amount of investment, e.g. for maintenance reasons.

[12] It is important to note that it would be very unlikely to observe so many firm-year observations with investment

Finally, it is worth noting the very low serial correlations of investment rates in all countries. Again, these low serial correlations suggest the presence of fixed adjustment costs; if the data were generated from a model with convex costs only (conditional on the autocorrelation of productivity), we would expect to observe significantly higher serial correlations in investment rates (see for example Cooper and Haltiwanger (2006)).[13]

In summary, the statistics reported in Table 4 strongly suggest the presence of significant fixed costs of adjustment and investment lumpiness. This is the distinctive feature we exploit in our sample in order to precisely test the predictions of our model.

# 5 Baseline specifications and estimation methodology

One of the key predictions of our model is that under costly external finance, firms will accumulate cash in non-spike periods and use the savings during periods of investment spikes in order to avoid the cost associated with using external finance. In order to test this prediction we focus on the estimation of the following empirical model, which relates the firm's accumulation of cash (savings) to total assets ratio ($\Delta Cash_{it}/TotalAssets_{it-1}$) to its cash flow to assets ratio, sales growth to assets ratio, and size (measured by the logarithm of its total assets). We then interact our cash flow variable with a dummy variable, which aims to control for the investment regime the firm is operating in. This leads to the following equation:

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rates above the investment spike threshold in the absence of fixed capital adjustment costs. In a world with convex adjustment costs only, most firm-year observations would in fact be characterized by small and continuous investment activity. Furthermore, there would be no or very rare evidence of investment inaction. These outcomes can be generated from a stripped down version of our model with convex capital adjustment costs. We do not present the results here to save space, but they are available upon request.

[13] For example with a standard calibration, a model with convex adjustment costs only would produce serial correlation in investment rates that significantly exceeds 0.50.

$$\frac{\Delta Cash_{it}}{TotalAssets_{it-1}} = \beta_0 + \beta_1 \frac{sales \quad growth_{it}}{TotalAssets_{it-1}} + \beta_2 \frac{CashFlow_{it}}{TotalAssets_{it-1}} * SPIKE_{it} + \beta_3 \frac{CashFlow_{it}}{TotalAssets_{it-1}} * (1 - SPIKE_{it}) + \beta_4 SIZE_{it-1} + \epsilon_{it} \quad (13)$$

where $SPIKE_{it}$ takes the value of one for firm-year observations with investment rates above 50% and zero otherwise. Note that the regression specification above is identical to the regression specification used in Section 3, since the $(k+b)$ in equation (11) corresponds to $SIZE$ in equation (13). It is a variant of the specification proposed by Almeida et al. (2004), who derive it from a model of corporate liquidity, and of the one by Khurana et al. (2006), Pal and Ferrando (2010), and Riddick and Whited (2009), who use it to investigate company financial policies and test for the presence of capital market imperfections. The crucial difference in our specification compared to theirs is the fact we control for the (potentially) differential effect of investment regimes on the savings–cash flow sensitivity.

As most of the firms in our sample are not listed on the stock market, we are unable to assess their market value. Hence, we control for investment opportunities in two different ways. First, following La Porta et al. (2000), Konings et al. (2003), Khurana et al. (2006), and Guariglia et al. (2012), we use the firm's sales growth, as a proxy for the firm's future profitability. In addition, we include time dummies interacted with industry dummies in all specifications. As discussed in Brown et al. (2009) and Brown and Petersen (2009), since these dummies account for all time-varying demand shocks at the industry level, their inclusion represents an indirect way to control for investment opportunities, or more general demand factors.

The error term in equation (13), $\epsilon_{it}$, comprises a firm-specific time-invariant component, encompassing all time-invariant firm characteristics likely to influence savings, as well as the time-invariant component of the measurement error affecting any of the regression variables; a time-specific component accounting for possible business cycle effects; and an idiosyncratic component. We control for the firm-specific time-invariant component of the error term by estimating the equation using a fixed effects estimator, and for the time-specific component by including time dummies (in addition to the time dummies interacted with industry dummies) in all our specifications.[14]

# 6 Main results

## 6.1 Savings specification controlling for investment regimes

The main prediction from the model is that the rate of cash accumulation will differ according to the investment regime. In particular, the sensitivity of savings to cash flow should be negative for firms that exhibit investment spikes, and positive otherwise, that is, the savings cash flow sensitivity should switch sign across investment regimes.[15]

In order to test this in our sample, we use the definition of investment spikes introduced in section 4.2, and classify the firms in the sample accordingly. Table 5 presents estimates of equation (13) for our four transition and four developed countries. In accordance with the prediction of the model, we observe that the cash flow sensitivity of savings varies significantly with the investment regime. In particular, the coefficients on $(\frac{CashFlow}{TotalAssets} * (1 - SPIKE))$, which capture the savings-cash flow sensitivities during periods of inactivity (or low activity), are always positive and statistically significant. They range from values of approximately 0.033 for Romania to 0.079 for Bulgaria in the transition group; and from 0.057 for Germany to 0.132 for Belgium in the

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[14] We have confirmed the robustness of our findings to using an Ordinary Least Squares (OLS) estimator (without controlling for fixed effects) as well as two Instrumental Variables (IV) estimators, namely, OLS-IV and system Generalized Method of Moments (GMM) (Blundell and Bond (1998)). However, given concerns with the appropriate selection of instruments and specification tests that accompany them (see Erickson and Whited (2012); and Roberts and Whited (2013) for a discussion) we chose to report only the fixed effects results. The OLS-IV and system GMM results are available upon request. The OLS results are reported in Appendix A, Table A.1.

[15] In Appendix A we report results from the standard specification that does not control for investment regimes (as in Almeida et al. (2004)). The findings from these specifications (see Table A.2) are in line with the findings in Almeida et al. (2004) and Khurana et al. (2006) who find positive and significant savings to cash flow sensitivities.

developed group. By contrast, the interaction terms between cash flow and the investment spike ($\frac{CashFlow}{TotalAssets} * (SPIKE)$) have negative and statistically significant coefficients in all cases. They range from -0.039 for Bulgaria to -0.058 for Czech Republic in the transition group, and from -0.047 for France to -0.083 for Belgium in the developed group. In addition, as indicated by the test of equality at the foot of Table 5 (p-values), the interactions between cash flow and the $SPIKE$ dummy are significantly different from the interactions between cash flow and the $(1 - SPIKE)$ dummy, at the 5% level, in all countries considered.[16] Overall, the results from this regression specification provide strong support to the predictions of our model.

As already discussed, the distinctive feature of our proposed specification, is that it controls for investment regimes. By contrast, the standard specification used in Almeida et al. (2004) or Riddick and Whited (2009), that does not account for investment regimes, cannot test the prediction that the cash flow sensitivity of cash accumulation should switch sign across different investment regimes. The fact that we have a sample that includes information from different investment regimes makes our proposed specification able to sharpen the test based on the standard savings specification. Because they work with much larger firms,[17] Riddick and Whited (2009) do not have this rich sample information and thus can only test a conditional model prediction. Finally, it is interesting to note that when Riddick and Whited (2009), (page 1763), examine a very small cross section of firms exhibiting lumpy investment, they report positive sensitivities of cash accumulation to cash flow, in line with our findings in Table 5.[18]

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[16] We have also experimented with alternative cut-offs to define the spikes (investment rates exceeding 60% and 70%) and found qualitatively similar results. The results are not reported for brevity, but available upon request.

[17] The average firm size in Riddick and Whited (2009)'s dataset is approximately 10 times larger than the average firm size in our sample.

[18] A noteworthy point made by Riddick and Whited (2009) on the use of savings–cash flow sensitivities as predictors of financing constraints is the potential confounding role of uncertainty on the size of the cash flow coefficient. In their model, more constrained firms are predicted to have larger negative coefficients compared to unconstrained firms. At the same time, they show that in the presence of a volatile productivity process, the size of the cash flow coefficient decreases in absolute value. Because in their sample, small (constrained) firms have more volatile productivity (income) processes compared to large (unconstrained) firms, it is found (in some sub-samples) that the cash flow coefficient is smaller (in absolute value) for smaller firms, thus going against the prediction of a larger (absolute) coefficient. Thus, uncertainty can confound the interpretation of the savings–cash flow sensitivity as a summary measure of financial constraints.

While a secondary issue for our purpose, it is worth noting that Riddick and Whited (2009) obtain a negative sensitivity even once they correct for measurement error in Tobin's $Q$ using the procedure explained in Erickson and Whited (2002). We note our approach side-steps the measurement error problem present in Tobin's $Q$ since our firms are unlisted and we use firm-specific and industry information to capture time varying demand factors and hence investment opportunities.[19] We thus believe, the differential sensitivities we obtain are unlikely to be due to measurement error.

## 6.2 Testing additional model predictions

Our main focus has been to examine the sensitivity of savings to cash flow controlling for investment lumpiness. However, our model makes additional predictions and we test them in this section. First, the model predicts that cash should be going down during periods of investment spikes, and gradually increase after those periods when investment activity is low. Second, it predicts that the cash flow sensitivity of savings should switch from positive to zero at some point after the firm has undergone an investment spike.

**First additional prediction.** Table 6 reports results from a specification that tests for the first additional prediction of our model. The equation we estimate is as follows:

$$\frac{\Delta Cash_{it}}{TotalAssets_{it-1}} = \beta_0 + \beta_1 \frac{sales \quad growth_{it}}{TotalAssets_{it-1}} + \beta_2 SPIKE_{it} + \beta_3 SPIKE_{it,14} + \beta_4 SIZE_{it-1} + \epsilon_{it} \quad (14)$$

The $SPIKE$ dummy is identical as in the baseline specification, whereas the new dummy,

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[19] D'Espallier and Guariglia (2015) shows that the investment opportunity bias is not a serious problem for unlisted firms.

$SPIKE_{14}$, records four subsequent periods after investment spike periods, requiring that they refer to low investment activity periods. We define low investment activity as those periods where investment rates do not exceed 15% (matching the average depreciation rate in our sample). That is, if an investment spike occurs in period $t$, $SPIKE_{14}$ will be equal to one in period $t+1, t+2, t+3, t+4$ if the average investment rate in those four periods does not exceed 15%, and zero otherwise. We observe that the coefficients on the $SPIKE$ dummy are significantly negative in all eight countries, while the coefficients on the $SPIKE_{14}$ dummy are in general significantly positive (with the exception of Romania and Germany). In line with the model's predictions, these results indicate that cash falls during spike periods and gradually builds up in the subsequent periods of low activity (or inactivity), suggesting firms are accumulating cash anticipating a future spike.

**Second additional prediction.** Table 7 reports results from a specification that tests for the second additional prediction of our model. The equation we estimate is as follows:

$$\frac{\Delta Cash_{it}}{TotalAssets_{it-1}} = \beta_0 + \beta_1 \frac{sales \quad growth_{it}}{TotalAssets_{it-1}} + \beta_2 \frac{CashFlow_{it}}{TotalAssets_{it-1}} * SPIKE_{it} + \\ \beta_3 \frac{CashFlow_{it}}{TotalAssets_{it-1}} * SPIKE_{it,14} + \beta_4 \frac{CashFlow_{it}}{TotalAssets_{it-1}} * OTHER_{it} + \beta_5 SIZE_{it-1} + \epsilon_{it} \quad (15)$$

The $SPIKE$ and $SPIKE_{14}$ dummies are identical as above and the new dummy $OTHER$ records periods that are neither spikes nor any of the four low investment activity periods after the spike. The $OTHER$ dummy seeks to capture those periods after cash buildup has run its course following a spike. We therefore test whether firms are accumulating cash during the periods after the spike, use this cash to finance the spike and revert to no cash accumulation in all other periods following the cash accumulation. We find (with the exception of Bulgaria and German that the cash flow sensitivity of cash accumulation switches from positive during $SPIKE_{14}$, to negative when the $SPIKE$ occurs (with the exception of Bulgaria). We also find support, in four out of eight cases, that the cash flow sensitivity switches to zero during $OTHER$, broadly supporting the second additional prediction of the model.

## 6.3 Robustness to an alternative investment spike definition

In the main specification we use in equation (13), the results of which are reported in Table 5, we define investment spikes as investment rates exceeding 50% for both groups of countries. In this section we examine the robustness of our results to an alternative measure of investment spikes. Specifically, we use one of the alternative measures of investment lumpiness reported in Table 4, based on the investment rates being at least 2.5 times above the firm-level median investment rate for each country and industry. This alternative measure, has the advantage of taking into account the norm of investment rates across countries and industries, which could be different due to technological factors (which could vary by industry) and other macroeconomic factors (which could vary by country). In this sense, it can be thought of as normalizing investment spikes across countries and industries. We report the estimation results in Table 8. To distinguish the new $SPIKE$ dummy from our baseline definition, we call it $SPIKE_{ROBUST}$. The results from this alternative measure are in line with our baseline results reported in Table 5. That is, the savings–cash flow sensitivity reverses sign according to the investment regime in all eight cases. Importantly, as indicated by the tests of equality at the foot of Table 8 (p-values), the coefficients on the interactions between cash flow and the $SPIKE_{ROBUST}$ dummy are always significantly different from the interactions between cash flow and the $(1 - SPIKE_{ROBUST})$ dummy, at the 5% level.

## 6.4 How might credit lines affect our results?

Recent literature on liquidity management suggests that bank credit lines can work as substitutes for cash. How might credit lines affect our empirical results? Credit lines allow firms to access pre-committed financing up to a certain quantity in exchange for the payment of a commitment fee (Almeida et al. (2013)). More specifically, credit lines can be seen as an insurance contract: The bank provides the firm with funds when the firm faces a liquidity shortfall and, in exchange, the bank collects payment from the firm when the firm does not need the funds under the line (Archaya et al. (2013)). Credit lines are widely used around the world: For instance, Lins et al. (2010) argue that "lines of credit are the dominant source of liquidity for most companies around the world, amounting to about 15% of assets". Along similar lines, Campello et al. (2011) show that access to credit lines was crucial in allowing firms to invest and survive during the recent financial crisis. Yet, Almeida et al. (2013) argue that whilst credit lines can be seen as an alternative to cash holdings, cash remains "king", in that it is "still the predominant way in which firms ensure future liquidity for future investments." One reason why this may be the case is that credit line contracts typically contain covenants that allow banks to restrict credit lines drawdowns if the covenants are violated (Sufi (2009)). Ippolito and Perez (2012) conclude that only firms in healthy conditions can meet the requirements imposed by the covenants attached to the credit lines. Another reason could be that bank lines of credit to firms with greater aggregate risk are costlier (Archaya et al. (2013)). A third reason may be that credit lines are issued with a precise stated purpose, which restricts their possible uses. Credit lines are therefore less flexible than cash (Ippolito and Perez (2012)). Finally, credit lines have a predetermined maturity, which limits their use for long-term investment (Ippolito and Perez (2012)). Lins et al. (2010) argue that non-operational cash guards against future cash flow shocks in bad times, while credit lines give firms the option to exploit future business opportunities available in good times. This suggests that the two types of liquidity are not perfect substitutes. Within our setting, if firms relied on credit lines instead of drawing down their cash reserves in order to finance investment spikes, we would not observe such large cash decumulation during spikes and cash accumulation thereafter. The fact that we do find these large effects indicates that lines of credit do not play such an important role in relation to investment spikes. Unfortunately, however, data on credit lines are not available within our dataset, so we are unable to test for these effects directly.

# 7 Conclusions

We propose a simple investment model with lumpy investment and cash accumulation and test a key prediction, namely, that under costly external finance, savings–cash flow sensitivities will vary significantly by investment regime. In line with the model, our empirical approach builds on a savings regression as in Almeida et al. (2004) and introduces an important modification—while nesting the latter—to control for investment regimes. This allows for a sharper empirical test of our model's key prediction, that focuses not on the sign of the sensitivity per se but on whether the sensitivity switches sign across investment regimes. We test this prediction using a panel of firms from transition and developed economies and find positive and significant savings-cash flow sensitivities for firms that operate in the investment inactivity (or low activity) regime, and negative and significant sensitivities for firms that operate in the investment spike regime.

We believe that the advantage of the modified specification we propose is its simplicity: it is easily applicable to a wide range of data sets, since it only requires one to find some occurrences of investment inactivity and investment bursts in order to define the $SPIKE$ dummy. In principle, as long as the sample contains small firms that tend to invest infrequently and more heavily compared to large firms, this should be possible. Alternatively, one could look at various types of investment spending and find those that typically involve large projects (such as investment in plant). This type of spending typically occurs in bursts (see for example Sakellaris (2004) for evidence), thus one could utilize such information in order to define spikes.

# A Appendix A

## A.1 Numerical solution and calibration

We apply value function iteration to solve the model. We discretize the state variables over a certain interval. The size of the interval is chosen in such a way that the variables remain in the state space during the simulations. The number of grid points per interval guarantees that the results are insensitive to using a finer grid. We discretize the state space of $k_t$ into 150 grid points, that of $b_t$ into 20 points, and that of $s_t$ into 10 points. The process for the productivity shock is approximated as a first order Markov process, using the method by Tauchen (1986). We form a guess for the value function, and based on this guess, we find policy functions that maximize the value function. We use the maximized value function obtained and repeat the procedure until convergence is achieved. We do not use a specific country as the basis for the calibration. Rather, we select parameter values that can be thought of as targeting the average of all countries. The results are robust to reasonable perturbations of the parameters. We set the risk-free rate equal to $2.65\%$. This value corresponds to the average (across countries) real yield for a 10 year government bond over the sample period. We set the discount factor, $\beta$, to 0.97, which implies $\beta(1+r) < 1$, a necessary assumption in order for cash to be dominated in the case without costly finance. This can be thought of as a higher discount rate of firm owners relative to the market's discount rate. We set the capital share in production, $\alpha$, at 0.7. Since we did not have any information from the sample, in order to be able to estimate or calibrate this parameter, we chose a value that implies decreasing returns to capital in production. We have experimented with varying this between 0.4 and 0.6, with no noticeable change in the results. Our chosen value is close to the one used by Cooper and Haltiwanger (2006). The depreciation rate is set at 0.15, in line with the ratio of total depreciation to capital in our sample. The capital adjustment cost parameters are set to the values reported in Cooper and Haltiwanger (2006), i.e we set the variable cost parameter, $\gamma$, at 0.049 and the fixed cost parameter, $F$, at 0.039. The parameter that determines the external finance cost, $\lambda$, is set equal to 0.07. This value implies a premium for using external funds equal to 7%. This choice is guided (though it is only an imprecise mapping) by the interest burden (i.e. the ratio of total interest expense to total debt) observed in our sample, which varies between 6% for the U.K. to 33% for Romania. Finally, the persistence and standard deviation of the idiosyncratic productivity shock are chosen in order to come as close as possible to the persistence and volatility of investment rates in our sample as reported in Table 4 and Table 3 (last row, standard deviation reported in parenthesis). Specifically, we set $\rho = 0.75$ and $\sigma = 0.2$. This gives a persistence in investment rates in our simulated sample (in the industry with costly external finance with 25,000 firm–year observations) equal to 0.14 and a standard deviation equal to 0.44, which are within the range of values observed in our sample (see Tables 3 and 4).[20]

To help the reader visualize how cash policy is affected by lumpy investment, the Figure below plots investment, cash and savings policies derived from a simple version of the model, whereby we have only allowed the choice of cash to be within a two point grid and the productivity shock to be within a three point grid (low, medium high). The black line denotes investment and associated cash policies when productivity is low. The green line denotes the corresponding policies when productivity is high. Thus, the shift from the black to the green line is caused by a positive cash flow shock. Notice that both investment and cash policies are non-linear (conditional on productivity). Firm investment oscillates between an activity regime, where the optimal investment spending depends on existing capital stock, and an inaction regime. Inaction occurs for all capital stocks to the right of the threshold level of capital. This threshold level is the one for which the value function generated from inaction is identical to the value function generated from activity. The associated cash policy follows a low-high pattern: to the left of the threshold level of capital the firm invests and cash balances are equal to zero, whereas to the right of this threshold, the firm does not invest and quickly accumulates positive cash balances to prepare for the next investment

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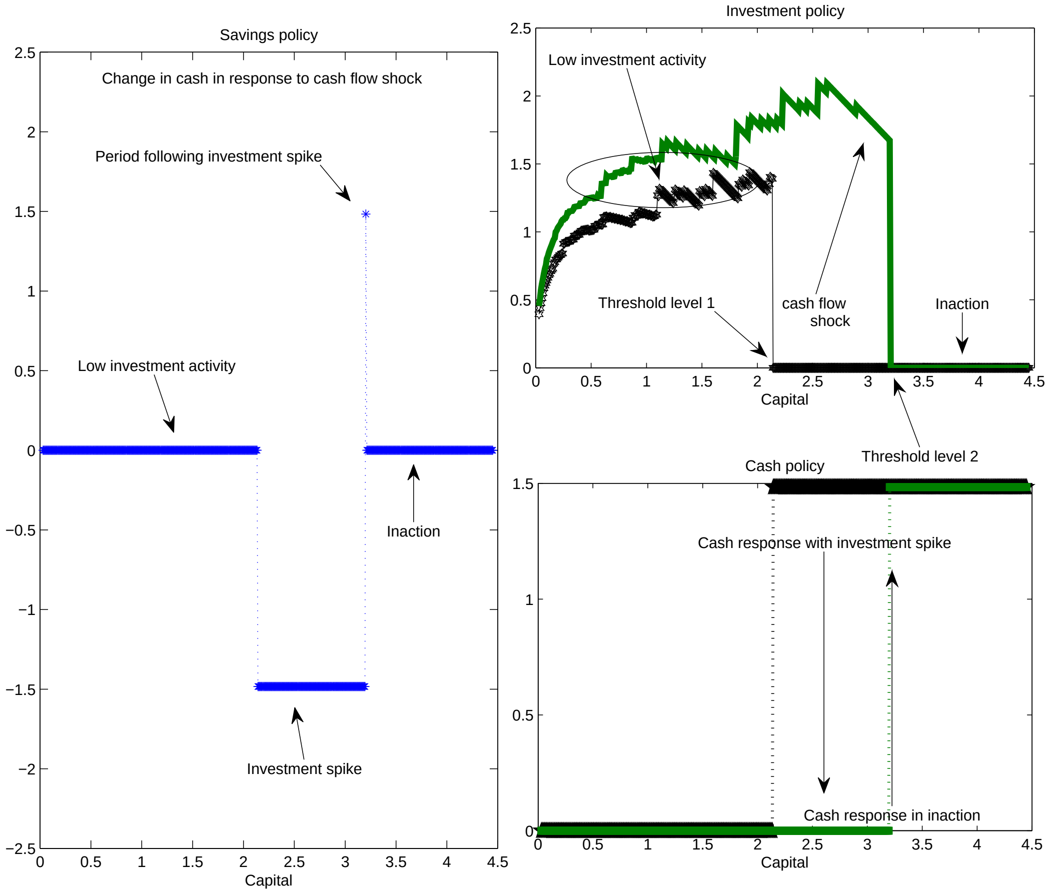
[20] Since we are only interested in simulating panels of firms, and not in matching, for example, industry dynamics, for simplicity, we ignore any common component in the productivity process across firms.

# Figure A1: Policy functions



*Notes*: The Figure plots investment policy, cash policy and savings policy generated by the model as functions of the capital stock. The policy functions are generated using the baseline calibration of the model. For ease of exposition and interpretation we have only allowed the choice of cash to be within a two point grid and the productivity shock to be within a three point grid (low, medium high).

episode. We can better understand the savings policy by analyzing two cases. In the first case, we assume the firm has capital between threshold level 1 and threshold level 2 and the productivity level is low. The firm is in an inactivity regime for this level of productivity (black line). Cash balances are positive (shown by the black line). Let a positive cash flow shock distort this situation as the firm experiences a high productivity shock. The optimal response is a burst of investment. This takes the firm somewhere on the green investment line. The optimal cash policy is given by the green line. Because cash flow is not sufficient, the firm quickly uses all of its cash to finance this investment spike and cash balances fall to zero. This investment spike will take the firm to the inaction regime (where the green investment line is zero) and associated cash balances will rise quickly (green positive line). In the second case, the firm begins with a capital stock strictly below the threshold level 1. In this case the high productivity shock generates low investment activity (in the simulation exercises of Section 3, this is normally associated with investment that replaces the depreciated capital stock). In this case however, cash balances do not change as a result of higher productivity, that is, cash flow suffices to finance this low investment activity and the firm hoards the cash in anticipation of a future investment spike. The left panel in the Figure plots the savings behavior. Savings is equal to zero, becomes negative during the spike and then positive after the spike. Once cash is built up to the optimal level, savings switches again to zero. Thus the savings–cash flow sensitivity switches sign from negative to positive around the episode of an investment spike, while it is zero during inaction or low activity spells. In the full model where the choice of cash is not only low or high but allows for more intermediate values, the savings–cash flow sensitivity is also positive for very low investment activity, that is cash balances may increase. To facilitate the illustration with the special case of the model, this feature is, however, not captured in this Figure.

## A.2 OLS estimator

We report results from estimating the main specification, equation (13), using an Ordinary Least Squares (OLS) estimator (without controlling for fixed effects) with White-corrected standard errors, adjusted to account for within cluster correlation. The results from this estimation method are reported in Table A.1 and are remarkably similar to those reported in Table 5 using the fixed effects estimator, confirming the key prediction of our model regarding the sign switch in the savings-cash flow sensitivity.

## A.3 Standard savings specifications

For comparison purposes with the earlier studies noted in the main body we also estimate the savings specification without the dummy $SPIKE_{it}$, i.e,

$$\frac{\Delta Cash_{it}}{TotalAssets_{it-1}} = \beta_0 + \beta_1 \frac{Salesgrowth_{it}}{TotalAssets_{it-1}} + \beta_2 \frac{CashFlow_{it}}{TotalAssets_{it-1}} + \beta_3 SIZE_{it-1} + \epsilon_{it} \quad (16)$$

The results from this specification are reported in Table A.2 and are in line with findings reported in Almeida et al. (2004) and Khurana et al. (2006).

## A.4 Sensitivity of the model's main prediction to model parameters

We examine the robustness of the model's main prediction, namely the sign switch of the savings–cash flow sensitivity to variation in model parameters. Similar to the exercise performed in Riddick and Whited (2009), we consider variation in the shock serial correlation, shock volatility, linear equity cost, returns to scale, fixed adjustment cost, and quadratic adjustment cost. Thus, we vary parameters one at a time while keeping all the other parameters at their baseline values. Tables A.3 to A.8 report these results. The sign switch in the savings cash flow sensitivity obtains for all parameter sets considered.

## A.5 Variable construction

This section provides the definition of variables used in the empirical section of the paper.

- $Total\ assets$: sum of the firm's fixed and current assets, where fixed assets include tangible fixed assets, intangible fixed assets, and other fixed assets; and current assets include inventories, accounts receivable, and other current assets.
- $Cash\ flow$: net income plus depreciation.
- $Cash$: cash and equivalents.
- $Fixed\ investment$: difference between the book value of tangible fixed assets (which include land and buildings; fixtures and fittings; and plant and vehicles) of end of year $t$ and end of year $t$-1, plus depreciation of year $t$.
- $Capital\ stock$: tangible fixed assets.
- $Sales\quad growth$: sales growth.
- $Sales$: firm's total sales (including domestic and overseas sales).
- $Deflators$: all variables are deflated using the GDP deflator for the relevant country.

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Figure 1: Investment rates by country

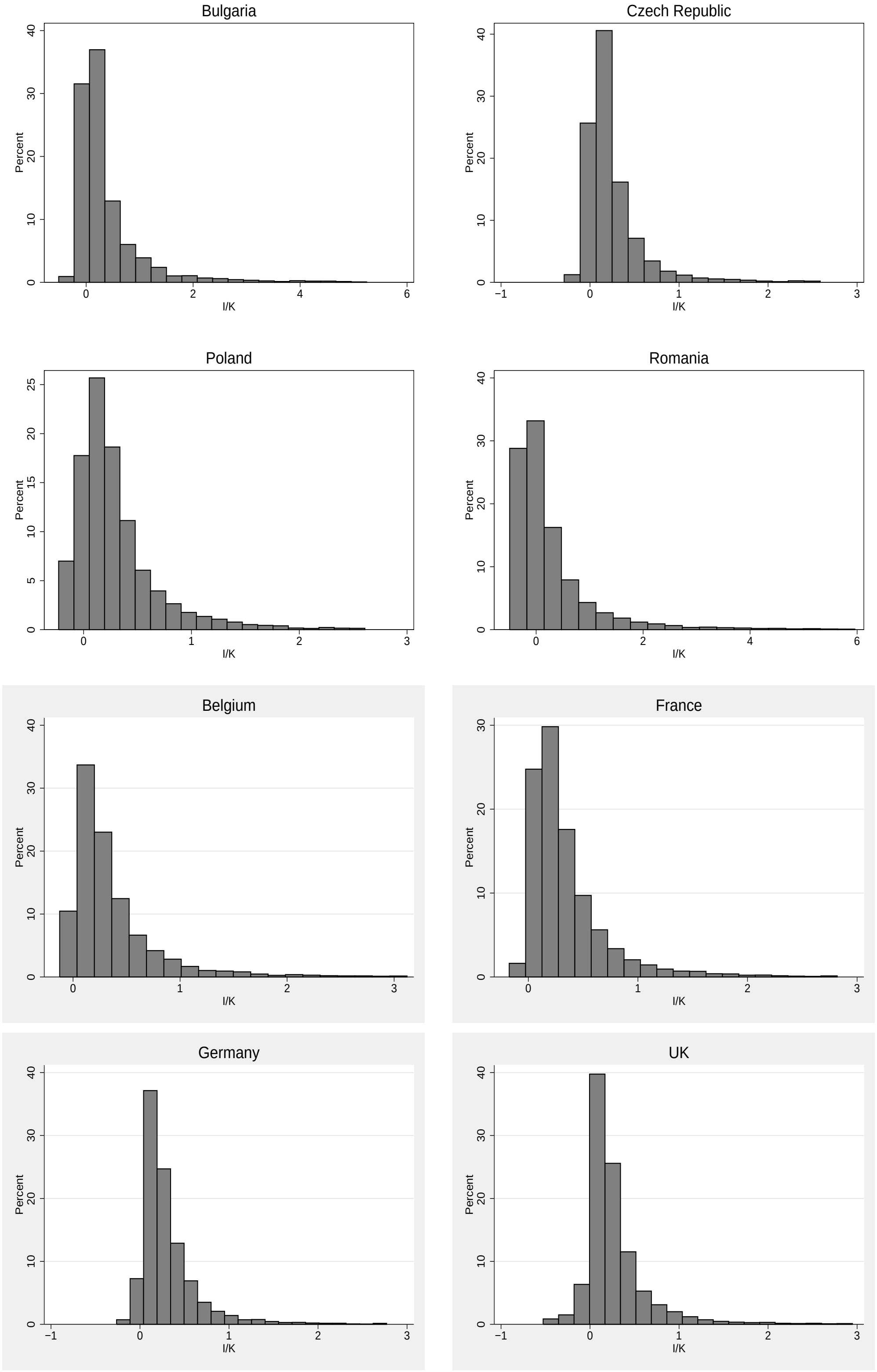

Table 1: Simulated savings regressions

| **Controlling for investment regime with SPIKE dummy** | | |
|---|---|---|
| | Panel with costly external finance | Panel with costless external finance |
| | (1) | (2) |
| $\frac{CashFlow}{b+k}*(1-SPIKE)$ | 0.085*** | 0 |
| | (0.011) | |
| $\frac{CashFlow}{b+k}*(SPIKE)$ | -0.985*** | 0 |
| | (0.016) | |
| $k+b$ | -0.014*** | 0 |
| | (0.0003) | |
| $\frac{salesgrowth}{b+k}$ | 0.129*** | 0 |
| | (0.008) | |
| $Observations$ | 25,000 | 25,000 |
| $\overline{R}^2$ | 0.43 | |
| Test of equality (p-value): Cash Flow | 0.00 | |
| **Conventional savings specification** | | |
| | Panel with costly external finance | Panel with costless external finance |
| $\frac{CashFlow}{b+k}$ | 0.106*** | 0 |
| | (0.010) | |
| $k+b$ | -0.005*** | 0 |
| | (0.0002) | |
| $\frac{salesgrowth}{b+k}$ | -0.278*** | 0 |
| | (0.009) | |
| $Observations$ | 25,000 | 25,000 |
| $\overline{R}^2$ | 0.06 | |

Notes: The dependent variable is $\frac{\Delta b_{it+1}}{b_{it}+k_{it}}$. All specifications were estimated using OLS. $SPIKE$ is a dummy variable that takes the value 1 for firm $i$ if firm $i$'s investment rate greater than 50%, and zero otherwise. The figures in parentheses are White-corrected standard errors, adjusted to account for within cluster correlation. * indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

Table 2: Simulated savings regressions: robustness to alternative parameterizations

**Controlling for investment regime with SPIKE dummy**

| | Baseline calibration | Perturbation I | Perturbation II | Perturbation III | Perturbation IV |
|---|---|---|---|---|---|
| | | $\delta$ = 0.30, $\sigma$ = 0.15, $\rho = 0.7$ | $\delta$ = 0.25,$\gamma$ = 0.01, F = 0.01, $\sigma$ = 0.15, $\rho = 0.7$ | F = 0.01, $\gamma$ = 0.01 | $\delta$ = 0.25 |
| $\frac{CashFlow}{b+k}$*$(1-SPIKE)$ | 0.085*** | 0.162*** | 0.243*** | 0.377*** | 0.117*** |
| | (0.011) | (0.017) | (0.020) | (0.028) | (0.008) |
| $\frac{CashFlow}{b+k}$*$(SPIKE)$ | -0.985*** | -0.458*** | -1.120*** | -0.816*** | -0.453*** |
| | (0.016) | (0.011) | (0.023) | (0.031) | (0.008) |
| $k+b$ | -0.014*** | -0.028*** | -0.009*** | -0.012*** | -0.0031*** |
| | (0.0003) | (0.002) | (0.0001) | (0.0002) | (0.002) |
| $\frac{salesgrowth}{b+k}$ | 0.129*** | 0.116*** | 0.027** | -0.199*** | -0.048*** |
| | (0.008) | (0.009) | (0.011) | (0.018) | (0.008) |
| $Observations$ | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 |
| $\overline{R}^2$ | 0.43 | 0.57 | 0.56 | 0.52 | 0.34 |
| Test of equality (p-value): Cash Flow | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Conventional savings specification**

| | Baseline calibration | Perturbation I | Perturbation II | Perturbation III | Perturbation IV |
|---|---|---|---|---|---|
| | | $\delta$ = 0.30, $\sigma$ = 0.15, $\rho = 0.7$ | $\delta$ = 0.25,$\gamma$ = 0.01, F = 0.01, $\sigma$ = 0.15, $\rho = 0.7$ | F = 0.01, $\gamma$ = 0.01 | $\delta$ = 0.25 |
| $\frac{CashFlow}{b+k}$ | 0.106*** | -0.102*** | 0.487*** | 0.306*** | -0.001 |
| | (0.010) | (0.015) | (0.022) | (0.024) | (0.005) |
| $k+b$ | -0.005*** | 0.061*** | -0.005*** | -0.007*** | 0.009*** |
| | (0.0002) | (0.001) | (0.0001) | (0.0003) | (0.001) |
| $\frac{Salesgrowth}{b+k}$ | -0.278*** | 0.366*** | -0.519*** | -0.427*** | -0.348*** |
| | (0.009) | (0.008) | (0.016) | (0.019) | (0.006) |
| $Observations$ | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 |
| $\overline{R}^2$ | 0.06 | 0.17 | 0.11 | 0.16 | 0.01 |

Notes: The dependent variable is $\frac{\Delta b_{it+1}}{b_{it}+k_{it}}$. All specifications were estimated using OLS. $SPIKE$ is a dummy variable that takes the value $1$ for firm $i$ if firm $i$'scinvestment rate is greater than 50%, and zero otherwise. The figures in parentheses are White-corrected standard errors, adjusted to account for within cluster correlation. *indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

## Table 3: Summary statistics

| | Bulgaria | Czech Republic | Poland | Romania | Belgium | France | Germany | UK |
|---|---|---|---|---|---|---|---|---|
| $Cash/A$ | 0.063 | 0.070 | 0.062 | 0.058 | 0.091 | 0.076 | 0.059 | 0.088 |
| | (0.094) | (0.083) | (0.083) | (0.085) | (0.124) | (0.106) | (0.096) | (0.121) |
| $\Delta Cash/A$ | 0.009 | 0.006 | 0.008 | 0.0008 | 0.004 | 0.003 | 0.002 | 0.006 |
| | (0.065) | (0.052) | (0.051) | (0.061) | (0.062) | (0.056) | (0.054) | (0.075) |
| Sales growth$/A$ | 0.178 | 0.130 | 0.165 | 0.016 | 0.042 | 0.072 | 0.065 | 0.007 |
| | (0.520) | (0.329) | (0.416) | (0.489) | (0.253) | (0.255) | (0.288) | (0.394) |
| $CashFlow/A$ | 0.107 | 0.104 | 0.129 | 0.132 | 0.107 | 0.088 | 0.099 | 0.101 |
| | (0.107) | (0.090) | (0.122) | (0.173) | (0.084) | (0.076) | (0.082) | (0.100) |
| $Cash$ | 2.179 | 6.086 | 5.422 | 1.547 | 17.415 | 18.823 | 26.452 | 39.472 |
| | (4.339) | (10.732) | (9.871) | (3.219) | (33.297) | (37.446) | (51.782) | (78.950) |
| $A$ | 63.008 | 128.806 | 115.832 | 38.526 | 314.768 | 404.065 | 795.584 | 704.554 |
| | (97.823) | (177.190) | (150.372) | (67.001) | (598.945) | (696.844) | (1342.83) | (1397.37) |
| $I/K$ | 0.319 | 0.221 | 0.263 | 0.169 | 0.350 | 0.344 | 0.304 | 0.261 |
| | (0.540) | (0.276) | (0.345) | (0.642) | (0.404) | (0.365) | (0.320) | (0.353) |
| $Observations$ | 2,250 | 7,479 | 5,428 | 4,513 | 8,475 | 21,574 | 3,204 | 10,214 |

Notes: $A$ represents the firm's total real assets (expressed in thousands of euros); $Cash$ represents real cash holdings, expressed in thousands of euros. $I$ represents investment; and $K$ the capital stock. The numbers in this Table are means, with standard deviations in parentheses. Also see Appendix A for precise definitions of all variables.

## Table 4: Investment lumpiness

| | Bulgaria | Czech Republic | Poland | Romania | Belgium | France | Germany | UK |
|---|---|---|---|---|---|---|---|---|
| Investment rates within 2% | 11.4% | 6.8% | 4.7% | 5.5% | 5.6% | 3.7% | 2.6% | 6.3% |
| Investment rates > 70% | 17.1% | 8.1% | 12.0% | 16.5% | 14.9% | 13.4% | 11.2% | 10.8% |
| Investment rates > 50% | 23.0% | 13.8% | 19.2% | 21.4% | 23.4% | 22.2% | 19.2% | 17.2% |
| Investment rates: 2.5 times above firm median | 18.2% | 11.5% | 8.4% | 36.6% | 12.6% | 31.5% | 51.7% | 47.5% |
| $\frac{\frac{I50}{K}}{\frac{I}{K}}$ | 0.81 | 0.32 | 0.68 | 0.89 | 0.59 | 0.40 | 0.31 | 0.61 |
| Correlation $(\frac{I}{K}, (\frac{I}{K})_{-1})$ | 0.13 | 0.09 | 0.14 | 0.01 | 0.25 | 0.26 | 0.36 | 0.25 |

Notes: Investment rates are defined as investment over capital ($\frac{I}{K}$). Firm level medians are computed separately for each country and industry. $\frac{I50}{K}$ is the total investment undertaken by those firms when there is a spike (defined as investment rates > 50%) divided by the capital stock of all firms in the sample.

Table 5: Savings specification controlling for investment regimes

| | Bulgaria | Czech Republic | Poland | Romania | Belgium | France | Germany | UK |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Sales\ growth$ | 0.020*** | 0.024*** | 0.005** | 0.022*** | 0.006 | 0.015*** | 0.020*** | -0.002 |
| | (0.003) | (0.003) | (0.002) | (0.003) | (0.004) | (0.002) | (0.005) | (0.003) |
| $Size$ | 0.012** | 0.005 | 0.003 | 0.005* | 0.017*** | 0.015*** | 0.011* | 0.031*** |
| | (0.005) | (0.003) | (0.004) | (0.003) | (0.004) | (0.002) | (0.006) | (0.004) |
| $CashFlow/A*SPIKE$ | -0.039* | -0.058*** | -0.046*** | -0.050*** | -0.083*** | -0.047*** | -0.053** | -0.048* |
| | (0.023) | (0.020) | (0.013) | (0.016) | (0.017) | (0.012) | (0.026) | (0.026) |
| $CashFlow/A*(1-SPIKE)$ | 0.079*** | 0.056*** | 0.071*** | 0.033** | 0.132*** | 0.112*** | 0.057** | 0.106*** |
| | (0.022) | (0.014) | (0.011) | (0.014) | (0.016) | (0.009) | (0.026) | (0.015) |
| $Observations$ | 2,250 | 7,479 | 5,428 | 4,513 | 8,475 | 21,574 | 3,204 | 10,214 |
| $Firms$ | 459 | 1,515 | 1,201 | 1,006 | 1,536 | 4,133 | 842 | 2,699 |
| $Test\ for\ equality$ | 0.001 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.007 | 0.000 |

*Notes*: The specifications were estimated using a Fixed-Effects estimator. The figures reported in parentheses are robust standard errors clustered by firm. $SPIKE$ is a dummy which equals one when investment rates are above 50%, and zero otherwise. Time dummies and time dummies interacted with industry dummies were always included in the specifications. Also see the Appendix for precise definitions of all variables. * indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

Table 6: Sensitivity of savings to investment spikes

| | Bulgaria | Czech Republic | Poland | Romania | Belgium | France | Germany | UK |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Sales\ growth$ | 0.019*** | 0.023*** | 0.002 | 0.018*** | 0.004 | 0.014*** | 0.020*** | -0.002 |
| | (0.005) | (0.003) | (0.002) | (0.003) | (0.004) | (0.002) | (0.005) | (0.003) |
| $Size$ | 0.013*** | 0.006* | 0.005 | 0.004* | 0.019*** | 0.016*** | 0.011* | 0.030*** |
| | (0.005) | (0.003) | (0.004) | (0.003) | (0.004) | (0.002) | (0.006) | (0.004) |
| $SPIKE$ | -0.013** | -0.010*** | -0.013*** | -0.007* | -0.012*** | -0.007*** | -0.008** | -0.007* |
| | (0.006) | (0.003) | (0.003) | (0.004) | (0.002) | (0.001) | (0.004) | (0.004) |
| $SPIKE_{14}$ | -0.006 | 0.005** | 0.002 | 0.002 | 0.005** | 0.004*** | 0.009** | 0.010*** |
| | (0.004) | (0.002) | (0.003) | (0.003) | (0.002) | (0.001) | (0.005) | (0.004) |
| $CashFlow/A$ | 0.089*** | 0.072*** | 0.096*** | 0.062*** | 0.148*** | 0.121*** | 0.056** | 0.150*** |
| | (0.021) | (0.014) | (0.011) | (0.012) | (0.016) | (0.009) | (0.026) | (0.015) |
| $Observations$ | 2,250 | 7,479 | 5,428 | 4,513 | 8,475 | 21,574 | 3,204 | 10,214 |
| $Firms$ | 459 | 1,515 | 1,201 | 1,006 | 1,536 | 4,133 | 842 | 2,699 |

*Notes*: The specifications were estimated using a Fixed-Effects estimator. The figures reported in parentheses are robust standard errors clustered by firm. $SPIKE$ is a dummy which equals one when investment rates are above 50%, and zero otherwise. $SPIKE_{14}$ is a dummy which equals one in the four periods right after the $SPIKE$ if the average investment rate does not exceed 15%, and zero otherwise. Time dummies and time dummies interacted with industry dummies were always included in the specifications. Also see the Appendix for precise definitions of all variables. * indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

Table 7: Investment spikes, cash build-up and other periods

| | Bulgaria | Czech Republic | Poland | Romania | Belgium | France | Germany | UK |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Sales\ growth$ | 0.022*** | 0.026*** | 0.007*** | 0.022*** | 0.009** | 0.017*** | 0.021*** | -0.002 |
| | (0.005) | (0.003) | (0.002) | (0.003) | (0.004) | (0.002) | (0.005) | (0.003) |
| $Size$ | 0.013*** | 0.004 | 0.003 | 0.005* | 0.015*** | 0.015*** | 0.011* | 0.029*** |
| | (0.005) | (0.003) | (0.004) | (0.003) | (0.004) | (0.002) | (0.006) | (0.004) |
| $CashFlow/A{*}SPIKE$ | -0.022 | -0.087*** | -0.054** | -0.078*** | -0.116*** | -0.087*** | -0.101* | -0.109*** |
| | (0.034) | (0.027) | (0.022) | (0.020) | (0.023) | (0.016) | (0.056) | (0.036) |
| $CashFlow/A{*}SPIKE_{14}$ | 0.019 | 0.057** | 0.053** | 0.068*** | 0.114*** | 0.107*** | 0.080 | 0.137*** |
| | (0.031) | (0.024) | (0.022) | (0.019) | (0.022) | (0.014) | (0.055) | (0.029) |
| $CashFlow/A{*}OTHER$ | 0.021 | 0.019 | 0.060*** | 0.019 | 0.091*** | 0.078*** | 0.037 | 0.073*** |
| | (0.029) | (0.015) | (0.013) | (0.017) | (0.017) | (0.010) | (0.026) | (0.017) |
| $Observations$ | 2,250 | 7,479 | 5,428 | 4,513 | 8,475 | 21,574 | 3,204 | 10,214 |
| $Firms$ | 459 | 1,515 | 1,201 | 1,006 | 1,536 | 4,133 | 842 | 2,699 |

*Notes*: The specifications were estimated using a Fixed-Effects estimator. The figures reported in parentheses are robust standard errors clustered by firm. $SPIKE$ is a dummy which equals one when investment rates are above 50%, and zero otherwise. $SPIKE_{14}$ is a dummy which equals one in the four periods right after the $SPIKE$ if the average investment rate does not exceed 15%, and zero otherwise. $OTHER$ is a dummy which equals one for all periods except $SPIKES$ and the $SPIKE_{14}$ periods, and zero otherwise. Time dummies and time dummies interacted with industry dummies were always included in the specifications. Also see the Appendix for precise definitions of all variables. * indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

Table 8: Measuring spikes in a different way

| | Bulgaria | Czech Republic | Poland | Romania | Belgium | France | Germany | UK |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Sales\ growth$ | 0.019*** | 0.023*** | 0.002 | 0.018*** | 0.003 | 0.014*** | 0.019*** | -0.002 |
| | (0.005) | (0.003) | (0.002) | (0.003) | (0.004) | (0.002) | (0.005) | (0.003) |
| $Size$ | 0.012** | 0.006* | 0.003 | 0.003 | 0.019*** | 0.016*** | 0.012** | 0.030*** |
| | (0.005) | (0.003) | (0.004) | (0.003) | (0.004) | (0.002) | (0.006) | (0.004) |
| $CashFlow/A$*$SPIKE_{ROBUST}$ | -0.065** | -0.090*** | -0.065*** | -0.046*** | -0.110*** | -0.058*** | -0.081** | -0.055** |
| | (0.031) | (0.022) | (0.016) | (0.015) | (0.021) | (0.015) | (0.037) | (0.028) |
| $CashFlow/A$*$(1-(SPIKE_{ROBUST})$ | 0.103*** | 0.082*** | 0.108*** | 0.086*** | 0.161*** | 0.128*** | 0.059** | 0.155*** |
| | (0.021) | (0.014) | (0.012) | (0.016) | (0.017) | (0.009) | (0.026) | (0.015) |
| $Observations$ | 2,250 | 7,479 | 5,428 | 4,513 | 8,475 | 21,574 | 3,204 | 10,214 |
| $Firms$ | 459 | 1,515 | 1,201 | 1,006 | 1,536 | 4,133 | 842 | 2,699 |
| $Test\ for\ equality$ | 0.001 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.007 | 0.000 |

*Notes*: The specifications were estimated using a Fixed-Effects estimator. The figures reported in parentheses are robust standard errors clustered by firm. $SPIKE_{ROBUST}$ is a dummy which equals one when investment rates are 2.5 higher than the median investment rate for each country and industry, and zero otherwise. Time dummies and time dummies interacted with industry dummies were always included in the specifications. Also see the Appendix for precise definitions of all variables. * indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

Table A.1: Savings specification controlling for investment regimes

| | Bulgaria | Czech Republic | Poland | Romania | Belgium | France | Germany | UK |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Sales\ growth$ | 0.021*** | 0.021*** | 0.005*** | 0.022*** | 0.010*** | 0.018*** | 0.018*** | 0.001 |
| | (0.004) | (0.003) | (0.002) | (0.002) | (0.003) | (0.002) | (0.004) | (0.002) |
| $Size$ | -0.001 | -0.002*** | -0.001 | 0.000 | -0.000 | -0.001*** | -0.002*** | 0.000 |
| | (0.001) | (0.000) | (0.001) | (0.001) | (0.001) | (0.000) | (0.001) | (0.001) |
| $CashFlow/A{*}SPIKE$ | -0.033 | -0.043*** | -0.036*** | -0.047*** | -0.063*** | -0.027*** | -0.027 | -0.036* |
| | (0.027) | (0.015) | (0.012) | (0.014) | (0.014) | (0.010) | (0.021) | (0.019) |
| $CashFlow/A{*}(1-SPIKE)$ | 0.059*** | 0.071*** | 0.067*** | 0.029*** | 0.092*** | 0.072*** | 0.054*** | 0.095*** |
| | (0.017) | (0.009) | (0.007) | (0.011) | (0.010) | (0.006) | (0.015) | (0.011) |
| $Observations$ | 2,250 | 7,479 | 5,428 | 4,513 | 8,475 | 21,574 | 3,204 | 10,214 |
| $Firms$ | 459 | 1,515 | 1,201 | 1,006 | 1,536 | 4,133 | 842 | 2,699 |
| $Test\ for\ equality$ | 0.016 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.006 | 0.000 |

*Notes*: The specifications were estimated using an OLS estimator. The figures in parentheses are White-corrected standard errors, adjusted to account for within cluster correlation. $SPIKE$ is a dummy which equals one when investment rates are above 50%, and zero otherwise. Time dummies and time dummies interacted with industry dummies were always included in the specifications. Also see the Appendix for precise definitions of all variables. * indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

Table A.2: Conventional savings specification

| | Bulgaria | Czech Republic | Poland | Romania | Belgium | France | Germany | UK |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Sales\ growth$ | 0.018*** | 0.022*** | 0.002 | 0.018*** | 0.003 | 0.013*** | 0.018*** | -0.002 |
| | (0.005) | (0.003) | (0.002) | (0.003) | (0.004) | (0.002) | (0.005) | (0.003) |
| $Size$ | 0.011** | 0.005 | 0.002 | 0.003 | 0.018*** | 0.015*** | 0.012* | 0.029*** |
| | (0.005) | (0.003) | (0.004) | (0.003) | (0.004) | (0.002) | (0.006) | (0.004) |
| $CashFlow/A$ | 0.086*** | 0.066*** | 0.090*** | 0.058*** | 0.139*** | 0.119*** | 0.050* | 0.147*** |
| | (0.021) | (0.014) | (0.011) | (0.011) | (0.016) | (0.009) | (0.026) | (0.015) |
| $Observations$ | 2,250 | 7,479 | 5,428 | 4,513 | 8,475 | 21,574 | 3,204 | 10,214 |
| $Firms$ | 459 | 1,515 | 1,201 | 1,006 | 1,536 | 4,133 | 842 | 2,699 |

*Notes*: The specifications were estimated using a Fixed-Effects estimator. The figures reported in parentheses are robust standard errors clustered by firm. Time dummies and time dummies interacted with industry dummies were always included in the specifications. Also see the Appendix for precise definitions of all variables. * indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

## Table A.3: Simulated savings regressions–robustness to using different values of the shock serial correlation

| **Controlling for investment regime with SPIKE dummy** | | | | | | |
|---|---|---|---|---|---|---|
| | $\rho$=-0.75 | $\rho$=-0.50 | $\rho$=-0.25 | $\rho$=0 | $\rho$=0.25 | $\rho$=0.50 |
| $\frac{CashFlow}{b+k}$*$(1-SPIKE)$ | 0.258*** | 0.403*** | 1.195*** | 0.879*** | 0.527*** | 0.199*** |
| | (0.014) | (0.025) | (0.089) | (0.077) | (0.055) | (0.022) |
| $\frac{CashFlow}{b+k}$*$(SPIKE)$ | -0.325*** | -0.652*** | -0.322*** | -1.689*** | -0.922*** | -1.186*** |
| | (0.021) | (0.043) | (0.097) | (0.116) | (0.074) | (0.041) |
| $k+b$ | -0.002*** | -0.003*** | -0.021*** | -0.027*** | -0.024*** | -0.018*** |
| | (0.0003) | (0.0003) | (0.0003) | (0.0005) | (0.0004) | (0.0003) |
| $\frac{salesgrowth}{b+k}$ | 0.287*** | 0.368*** | -0.344*** | -0.281*** | -0.327*** | -0.103*** |
| | (0.008) | (0.013) | (0.039) | (0.035) | (0.028) | (0.014) |
| $Observations$ | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 |
| $\overline{R}^2$ | 0.81 | 0.66 | 0.62 | 0.62 | 0.51 | 0.43 |
| Test of equality (p-value): Cash Flow | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Notes: The dependent variable is $\frac{\Delta b_{it+1}}{b_{it}+k_{it}}$. All specifications were estimated using OLS. In each column reported all other model parameters are held fixed at their baseline values. $SPIKE$ is a dummy variable that takes the value 1 for firm $i$ if firm $i$'scinvestment rate is greater than 50%, and zero otherwise. The figures in parentheses are White-corrected standard errors, adjusted to account for within cluster correlation. *indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

## Table A.4: Simulated savings regressions–robustness to using different values of the shock volatility

| **Controlling for investment regime with SPIKE dummy** | $\sigma$=0.05 | $\sigma$=0.10 | $\sigma$=0.15 | $\sigma$=0.25 |
|---|---|---|---|---|
| $\frac{CashFlow}{b+k}$*$(1-SPIKE)$ | 0.881*** | 0.148*** | 0.211*** | 0.189*** |
| | (0.113) | (0.026) | (0.019) | (0.013) |
| $\frac{CashFlow}{b+k}$*$(SPIKE)$ | -0.548*** | -1.380*** | -1.402*** | -0.694*** |
| | (0.144) | (0.036) | (0.048) | (0.025) |
| $k+b$ | -0.021*** | -0.017*** | -0.019*** | -0.018*** |
| | (0.0003) | (0.0003) | (0.0003) | (0.0004) |
| $\frac{salesgrowth}{b+k}$ | 0.001 | 0.277*** | 0.035*** | -0.120*** |
| | (0.036) | (0.015) | (0.011) | (0.007) |
| $Observations$ | 25,000 | 25,000 | 25,000 | 25,000 |
| $\overline{R}^2$ | 0.67 | 0.59 | 0.43 | 0.29 |
| Test of equality (p-value): Cash Flow | 0.00 | 0.00 | 0.00 | 0.00 |

Notes: The dependent variable is $\frac{\Delta b_{it+1}}{b_{it}+k_{it}}$. All specifications were estimated using OLS. In each column reported all other model parameters are held fixed at their baseline values. $SPIKE$ is a dummy variable that takes the value 1 for firm $i$ if firm $i$'scinvestment rate is greater than 50%, and zero otherwise. The figures in parentheses are White-corrected standard errors, adjusted to account for within cluster correlation. *indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

# Table A.5: Simulated savings regressions–robustness to using different values of the linear finance cost

| **Controlling for investment regime with SPIKE dummy** | $\lambda$=0.01 | $\lambda$=0.02 | $\lambda$=0.03 | $\lambda$=0.04 | $\lambda$=0.05 | $\lambda$=0.06 |
|---|---|---|---|---|---|---|
| $\frac{CashFlow}{b+k}$*$(1-SPIKE)$ | 0.272*** | 0.162*** | 0.219*** | 0.225*** | 0.173*** | 0.174*** |
| | (0.020) | (0.013) | (0.015) | (0.013) | (0.015) | (0.016) |
| $\frac{CashFlow}{b+k}$*$(SPIKE)$ | -0.417*** | -0.895*** | -0.888*** | -0.905*** | -0.973*** | -1.018*** |
| | (0.020) | (0.019) | (0.027) | (0.026) | (0.028) | (0.029) |
| $k+b$ | -0.008*** | -0.014*** | -0.016*** | -0.018*** | -0.018*** | -0.091*** |
| | (0.0002) | (0.0003) | (0.0004) | (0.0003) | (0.0004) | (0.0003) |
| $\frac{salesgrowth}{b+k}$ | -0.315*** | -0.006 | -0.161* | 0.007 | 0.019** | 0.004 |
| | (0.0002) | (0.008) | (0.009) | (0.009) | (0.009) | (0.009) |
| $Observations$ | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 |
| $\overline{R}^2$ | 0.27 | 0.40 | 0.28 | 0.32 | 0.32 | 0.33 |
| Test of equality (p-value): Cash Flow | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Notes: The dependent variable is $\frac{\Delta b_{it+1}}{b_{it}+k_{it}}$. All specifications were estimated using OLS. In each column reported all other model parameters are held fixed at their baseline values. $SPIKE$ is a dummy variable that takes the value 1 for firm $i$ if firm $i$'scinvestment rate is greater than 50%, and zero otherwise. The figures in parentheses are White-corrected standard errors, adjusted to account for within cluster correlation. *indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

# Table A.6: Simulated savings regressions–robustness to using different values of the returns to scale

| **Controlling for investment regime with SPIKE dummy** | $\alpha$=0.50 | $\alpha$=0.60 | $\alpha$=0.80 | $\alpha$=0.90 |
|---|---|---|---|---|
| $\frac{CashFlow}{b+k}$*$(1-SPIKE)$ | 0.037*** | 0.065*** | 0.207*** | 0.207*** |
| | (0.009) | (0.009) | (0.012) | (0.012) |
| $\frac{CashFlow}{b+k}$*$(SPIKE)$ | -0.461*** | -0.517*** | -0.001*** | -1.504*** |
| | (0.025) | (0.025) | (0.038) | (0.038) |
| $k+b$ | -0.047*** | -0.031*** | -0.001*** | -0.001*** |
| | (0.033) | (0.001) | (0.0000) | (0.0000) |
| $\frac{salesgrowth}{b+k}$ | -0.028*** | -0.054*** | -0.130*** | -0.130*** |
| | (0.007) | (0.007) | (0.010) | (0.010) |
| $Observations$ | 25,000 | 25,000 | 25,000 | 25,000 |
| $\overline{R}^2$ | 0.19 | 0.17 | 0.45 | 0.46 |
| Test of equality (p-value): Cash Flow | 0.00 | 0.00 | 0.00 | 0.00 |

Notes: The dependent variable is $\frac{\Delta b_{it+1}}{b_{it}+k_{it}}$. All specifications were estimated using OLS. In each column reported all other model parameters are held fixed at their baseline values. $SPIKE$ is a dummy variable that takes the value 1 for firm $i$ if firm $i$'scinvestment rate is greater than 50%, and zero otherwise. The figures in parentheses are White-corrected standard errors, adjusted to account for within cluster correlation. *indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

## Table A.7: Simulated savings regressions–robustness to using different values of the fixed adjustment cost

| **Controlling for investment regime with SPIKE dummy** | F=0.0 | F=0.01 | F=0.02 | F=0.03 |
|---|---|---|---|---|
| $\frac{CashFlow}{b+k}$*$(1-SPIKE)$ | 0.470*** | 0.676*** | 0.335*** | 0.307*** |
| | (0.054) | (0.065) | (0.026) | (0.019) |
| $\frac{CashFlow}{b+k}$*$(SPIKE)$ | -0.718*** | -0.807*** | -0.982*** | -0.963*** |
| | (0.052) | (0.062) | (0.048) | (0.042) |
| $k+b$ | -0.005*** | -0.013*** | -0.014*** | -0.018*** |
| | (0.0004) | (0.0005) | (0.0003) | (0.0003) |
| $\frac{salesgrowth}{b+k}$ | -0.434*** | -0.465*** | -0.295*** | -0.258*** |
| | (0.043) | (0.043) | (0.014) | (0.015) |
| $Observations$ | 25,000 | 25,000 | 25,000 | 25,000 |
| $\overline{R}^2$ | 0.20 | 0.36 | 0.34 | 0.36 |
| Test of equality (p-value): Cash Flow | 0.00 | 0.00 | 0.00 | 0.00 |

Notes: The dependent variable is $\frac{\Delta b_{it+1}}{b_{it}+k_{it}}$. All specifications were estimated using OLS. In each column reported all other model parameters are held fixed at their baseline values. $SPIKE$ is a dummy variable that takes the value 1 for firm $i$ if firm $i$'scinvestment rate is greater than 50%, and zero otherwise. The figures in parentheses are White-corrected standard errors, adjusted to account for within cluster correlation. *indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.

# Table A.8: Simulated savings regressions–robustness to using different values of the quadratic adjustment cost

| | **Controlling for investment regime with SPIKE dummy** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\gamma$=0.0 | $\gamma$=0.01 | $\gamma$=0.02 | $\gamma$=0.03 | $\gamma$=0.04 | $\gamma$=0.05 | $\gamma$=0.06 | $\gamma$=0.07 | $\gamma$=0.08 | $\gamma$=0.09 | $\gamma$=0.1 |
| $\frac{CashFlow}{b+k}*(1-SPIKE)$ | 0.017*** | 0.107*** | 0.107*** | 0.112*** | 0.154*** | 0.191*** | 0.178*** | 0.161*** | 0.182*** | 0.223*** | 0.248*** |
| | (0.008) | (0.012) | (0.013) | (0.013) | (0.014) | (0.011) | (0.014) | (0.014) | (0.014) | (0.017) | (0.010) |
| $\frac{CashFlow}{b+k}*(SPIKE)$ | -1.815*** | -1.258*** | -1.304*** | -1.246*** | -1.161*** | -1.150*** | -1.001*** | -1.001*** | -0.846*** | -0.791*** | -0.765*** |
| | (0.017) | (0.022) | (0.024) | (0.023) | (0.022) | (0.041) | (0.034) | (0.033) | (0.032) | (0.033) | (0.030) |
| $k+b$ | -0.011*** | -0.017*** | -0.018*** | -0.018*** | -0.018*** | -0.017*** | -0.017*** | -0.017*** | -0.017*** | -0.019*** | -0.021*** |
| | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0003) | (0.0004) | (0.0003) | (0.0004) | (0.0004) | (0.0003) |
| $\frac{salesgrowth}{b+k}$ | -0.037*** | 0.114*** | 0.090*** | 0.104*** | 0.079*** | -0.039*** | -0.025** | -0.038*** | -0.015 | -0.109*** | -0.139*** |
| | (0.006) | (0.008) | (0.009) | (0.008) | (0.010) | (0.008) | (0.009) | (0.010) | (0.010) | (0.012) | (0.009) |
| $Observations$ | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 |
| $\overline{R}^2$ | 0.56 | 0.47 | 0.48 | 0.46 | 0.45 | 0.34 | 0.31 | 0.32 | 0.30 | 0.32 | 0.35 |
| Test of equality (p-value): Cash Flow | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Notes: The dependent variable is $\frac{\Delta b_{it+1}}{b_{it}+k_{it}}$. All specifications were estimated using OLS. In each column reported all other model parameters are held fixed at their baseline values. $SPIKE$ is a dummy variable that takes the value 1 for firm $i$ if firm $i$'scinvestment rate is greater than 50%, and zero otherwise. The figures in parentheses are White-corrected standard errors, adjusted to account for within cluster correlation. *indicates significance at the 10% level. ** indicates significance at the 5% level. *** indicates significance at the 1% level.