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Stockpiling cash when it takes time to build: Exploring price differentials in a commodity boom[☆]

Erwin Hansen[a], Rodrigo Wagner[a,b,*]

[a] School of Economics and Business, University of Chile, Santiago, Chile
[b] Center for International Development Harvard. Cambridge, MA, USA

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ABSTRACT

Some projects take time to build or are slow to yield cash flows. This may impact the dynamics of investment and liquidity management, although few studies test their financial implications. We exploit the peculiar advantages of copper mines as a laboratory to identify cash-flow sensitivities. In this context, investment decisions depend on the expectations of the long run price of the commodity, while the spread between the spot price and this long run expectations shifts current cash-flows. For this study we compiled a sample of copper firms between 2002 and 2012. We do not find significant effects of cash flow on current capital expenditures, but we do observe a systematic cash flow sensitivity of cash holdings, meaning that some of these transitory earnings are retained as liquidity. This cash stockpiling is stronger among financially constrained firms. In a context of time-to-build, our findings support financial theories emphasizing the salience of cash as buffer stock for liquidity in preparation for future investment opportunities.

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1. Introduction

Some projects take a long time-to-build their capital or are slow to generate additional production. (e.g. Majd and Pindyck, 1987; Caballero, 1999; Kalouptsidi, 2014; Greenwood and Hanson, 2015). As examples, these projects in which investment takes a long time are salient in industries like ship and aircraft building, as well as some types of construction, forestry and mining. They are also relevant because they tend to be associated to investment cycles.[1] From a methodological point of view, in this paper we argue that these industries with time-to-build could help in one crucial empirical challenge of the financial literature that looks for cash-flow sensitivities as a measure of financial constraints (e.g. Fazzari et al. 1988; Kaplan and Zingales 1997a; Almeida et al. 2004). The usual identification problem in this literature is that a positive shift in fundamentals could simultaneously generate incentives to invest

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[*] Corresponding author.
E-mail addresses: ehansen@fen.uchile.cl (E. Hansen), rodrigo_wagner@post.harvard.edu (R. Wagner).

[1] For time to build in manufacturing industries see Koeva-Brooks (2000), Mayer and Sonenblum (1955); for mining see for example Slade (2013); for shipbuilding see Greenwood and Hanson (2015) and Kalouptsidi (2014). The literature that explores time-to-build tends to focus on the real side of the problem, for example characterizing investment cycles and lumpiness of decisions (e.g. Caballero, 1999; Kalouptsidi, 2014; Greenwood and Hanson, 2015). The literature tends to pay little attention to the financial decisions, which is a relevant gap since these projects could be among the most sensitive to financial constraints and impact investment cycles. One notable exception that explores the financial side is the current working paper by Drobetz et al. (2015), who explore cash flow sensitivity in bulk shipping. Unlike their study, we have source of identification to separate the incentives to invest from cash flow of the company. Also, they emphasize the fact that shipping is an asset heavy industry. Our point focuses more on the fact that they take time to be built.

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today, but also generates more liquidity due to current cash flows. For that reason Kaplan and Zingales (1997b) argue that the standard OLS regression explaining investment would estimate a positive and significant coefficient for cash-flows regardless of financial constraints. We argue that this frequent empirical problem of an omitted variable bias could be mitigated in industries with time-to-build, because the incentives to invest depend on long run fundamentals, while current cash-flows could be shifted by a transitory component that does not affect the fundamentals that define investment.

In this paper we precisely take advantage of these features studying copper mining; an industry with time-to-build and for which we can have separate proxies for long and short run profitability. In particular, investment in copper mines is determined by the expectations of the long run copper price, while short run deviations between the spot price and this long run expectation do not generate incentives to invest, because by the time this investment matures, the transitory component of price would vanish in expectation. This cash windfall created by the spread is the core of our identification strategy.

To perform our study we built a panel of both listed and unlisted copper firms around the world between 2002 and 2012. This was a period of a price boom, with surges in the long run price but also meaningful deviations between the spot price and this long run expectation. This spread is our instrument for cash-flows.

Using instrumental variables we examined two types of tests for financial constraints in this sample of copper firms. As suggested before, the first symptom is the well known cash-flow sensitivity of investment (CFSI) as in Fazzari et al. (1988). The logic is that constrained firms tend to invest more when they have more cash-flows, something that may not happen to financially unconstrained firms, which can invest when needed, not only when they have liquidity. In our setting of time-to-build this usual sensitivity of investment may be less likely to be detected, because the funding of investment today was decided looking at financial conditions of some years ago and because of the constraints to the speed of investment.

The second and stronger symptom we explore is about*future* financial constraints. We look at cash-stockpiling as a signal that forward looking firms are preparing themselves for future investments. The story goes as follows: the firm is expecting future constraints to finance a project, and therefore it accumulates a larger fraction of their current cash-flow as cash holdings in the balance sheet. This increases future liquidity that would be useful for future investment. To link this to the previous literature Almeida et al. (2004) call this phenomenon the *cash-flow sensitivity of cash* (CFSC), where the second mention of the word cash is for cash-holdings rather than cash-flows. In sum, we will be focusing on how much firms stockpile cash out of an additional dollar of transitory earnings.

Our setting seems particularly relevant for testing this theory of cash stockpiling, because this theory is built on the essential assumption that there are future investment opportunities which cannot be executed today. Without such a technological delay in investment opportunities Almeida et al. (2004)'s model would not predict that firms stockpile cash. Our setting of time-to-build in the copper industry is in fact an extreme case of delayed investment opportunities, in which projects take a long time to plan and execute. Moreover, our results are consistent with the theory's prediction. We find that financially constrained firms tend to stockpile a relevant fraction of the cash coming from transitory earnings. In other words there is a positive and statistically significant CFSC.

In contrast to CFSC, the cash flow sensitivity of investment (CFSI) is almost always statistically insignificant. We are not claiming that cash-flows have exactly a zero effect on the investment of constrained firms. Instead, we argue that in the case CFSI is not zero, it is still difficult to obtain precise estimates of the CFSI because of heterogeneous delays between the financial decisions and actual investment, which is a central characteristic of the industry. Our main message is that with time-to-build CFSC might be a preferred measure of financial constraints compared to CFSI.[2]

Our central results survive a large battery of robustness tests. For example we show that this behavior holds both for listed and unlisted companies. We also try different definitions for financial constraints (i.e. size, credit rating) and for long run copper prices. We added various time varying controls to test for measurement problems or explanations that could challenge our identification. Our results remained robust..

Beyond our central finding of cash-holdings as a financial buffer under conditions of time-to-build, our work is connected to at least three areas of the literature. A first connection of our work is to other papers in the literature that instrument cash-flows using various natural experiments (e.g. Blanchard, Lopez-de Silanes and Shleifer, 1994; Tufano, 1996; Lamont, 1997; Rauh, 2006).[3] Some of these papers use exogenous shocks to prices to mitigate the endogeneity of cash flows to long run investment fundamentals. The difference with our study is that we are the first to exploit the *difference* between spot and long run expected prices to mitigate that endogeneity.[4] Our story is meaningful only given conditions of time-to-build, which make current prices less relevant for investment decisions.

A second link of our paper relates to the literature measuring investment opportunities. In two extensive summaries of the literature both Hubbard (1998) and Caballero (1999) argue that in investment regressions there is usually little significance or magnitude for the coefficient on Tobin's Q, while there tend to be positive effects for measures such as cash-flows. Erickson and Whited (2000, 2012) argue that this could be due to measurement error in Tobin's Q, which inflates cash-flow sensitivities and dilutes the coefficient for Q. We do not use Tobin's Q but instead replace it with expectations of the long run price of the commodity, as a shifter for investment possibilities. When we test both proxies of

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[2] Various papers that tested both CFSI and CFSC found that *both* CFSI and CFSC are significant; but they do not focus on industries with time to build. Using alternative econometric approaches and empirical specifications D'Espallier et al. (2008), Dasgupta et al. (2011) and Gatchev et al. (2010) report positive and statistically significant estimates for *both* cash flow sensitivity estimates. A similar result is also found by Almeida et al. (2004) for CFSC and Almeida and Campello (2007) for CFSI independently but using a similar sample of manufacturing firms in the US.

[3] Within this cash-flow-sensitivity literature we aim at contributing to the much less prolific set of papers that are identified with a strategy beyond lags and other covariates. Blanchard et al. (1994) explores eleven event studies in which companies were awarded a cash windfall after a judicial procedure. Lamont (1997) explores internal capital markets of conglomerates (multi-segment firms) that include an oil company, looking at the oil price drop in 1986. Rauh (2006) exploits the cash flow shocks induced by unpredicted returns of the corporate pension plans for employees. Out of financial economics various studies have used movements in the main export commodity of a country as a shifter for its exchange rate (e.g.Chen, Rogoff and Rossi, 2010; Chen and Rogoff, 2003; Cashin, Céspedes and Sahay, 2004).

[4] Andrén and Jankensgård (2015) also uses a relatively smaller sample of firms to study how commodity price changes impact funding, specifically in the gas and oil industry. They find that financially constrained firms reduce their investment sensitivity to earnings when commodity prices jumped. We have significant differences with their approach. First, we study both sensitivity of investment and cash holdings to changes in earnings. Second, they claim to identify a shift in liquidity, not only because of earnings but also because the assets of the company became more valuable after the commodity boom, which allowed taking extra debt. Unfortunately that shock to liquidity is by construction correlated with the expectation of future investment opportunities (the demand for funding). We avoid that challenge by focusing on transitory rather than permanent changes, explicitly using an IV approach to identify the liquidity shock. We are also close to Hovakimian (2009) who looks for the determinants of investment cash-flow sensitivity of cash. Again, our innovation vis-à-vis these papers is the aim for causality and especial concern for cash holding rather than investment. Carter et al. (2006) also uses a relatively small panel, but in the airline industry, to explore how hedging impacts a company's value after oil price changes.

investment opportunities our long-run price expectations appear significant when explaining investment, while Tobin's Q loses statistical significance. Possibly in our setting the long-run price is a better proxy for changes in *marginal* Q - the value of the marginal project over its book value - than the usual measure of *average* Q, which comes from market valuations of the average project in the firm (see Hayashi, 1982; Tobin, 1969; Bolton et al., 2011).

Both Hubbard (1998) and Caballero (1999) also argue that there could be other challenges beyond measurement error in Tobin's Q that could explain its lack of significance; for example investment lumpiness and time-to-build, which are central features of our setting. This leads to the third and probably strongest connection between our paper and the literature. Tsoukalas (2011) argues that time-to-build can induce a spurious correlation between investment and cash, even when Tobin's Q is perfectly measured. Although we aim to correct for this effect, our goal with time-to-build is rather different: we exploit it for identification because in our setting a short run jump in spot prices does not change the incentives to invest. Our method could be applied to other contexts with time-to-build, if *different* proxies for short and long run profitability are available (e.g. bulk shipping as in Kalouptsidi, 2014; Greenwood and Hanson, 2015; Drobetz et al., 2015).

The remainder of the paper is structured as follows. Section 2 describes a simplified theoretical framework. Section 3 explains the institutional context of time-to-build. Section 4 explains how we built our dataset, describing its main patterns. Section 5 contains the core empirical results of our paper, estimating cash flow sensitivities of investment and cash holdings, while Sections 6–8 perform a series of robustness checks and additional tests. Finally, Section 9 concludes with some remarks. The Appendix displays the reduced form of our IV regressions, while other analysis are left to our Online Appendix.

2. Theoretical framework

While the contribution of this paper is essentially empirical, in order to attempt identification this section builds a stylized framework to help outline our empirical strategy.

This theoretical framework is a reduced form adapted from Almeida et al. (2004); who explore the inter-temporal decision of corporations to save in cash holdings. This is a suitable starting point given the time-to-build. In their model, financially constrained firms choose their optimal stock of cash holdings h^*as a result of a trade off between the marginal cost of hoarding an extra unit of cash $C'(h_t)$ and the marginal benefit of doing so $B'(h_t)$. The cost of cash today is essentially the opportunity cost of *not* undertaking a *current* project with positive NPV, which without loss of generality could also be a liquid investment outside the firm. In contrast, the benefit of increasing savings in cash within the firm is determined by the option of investing in the future, plus some basic liquidity needs. Adapting Almeida et al. (2004)'s framework we obtain the familiar condition that - at the optimum - marginal costs and benefits equalize:

$$C'(h_t, X^C) = B'(h_t, X^B);$$

where X^C and X^B are variables that shift the marginal cost and benefit curves above. A crucial distinction is that for financially constrained firms the marginal cost is the internal marginal cost of resources $C'_{int}(h_t, X^C)$. In contrast, for unconstrained firms the marginal cost is simply equal to the marginal cost of external funds, namely $C'(h_t, X^C) = r^{External}$.

Fig. 1 depicts the graphical solution for optimal cash holdings, showing the effect of an exogenous and *transitory* increase in cash flow, which shifts the marginal cost of internal funds to the right, without moving the benefits of investment.

In preparation for our empirical exercise in Section 5 a few considerations are relevant. First, it is important to note that the marginal benefit curve of holding cash $B'(h_t, X^B)$ does in fact move when there is a shift in future investment opportunities (for example due to an increase in the expected long run price $P_t^{LR} \in X^B$), but only for financially constrained firms. In contrast, for financially unconstrained firms the same shift in investment opportunities does *not* translate into a shift in marginal benefit of holding cash $B'(h)$, since resources for this future investment could be financed externally in that same future date. In that case there is no additional option value of stockpiling cash today.

There is an important distinction between a transitory and a permanent (long run) price change. As mentioned, the shift in transitory cash flows only shifts the cost curve $C'(.)$ to the right, while *ceteris paribus* the benefits of holding cash $B'(.)$ do not move, predicting an increase in cash holdings. In contrast, a change in the long run price of copper moves both the marginal cost and marginal benefits of holding cash, movements that could even be in different directions. In particular, for financially constrained firms there is an increase in the value of investing cash holdings *today* (even if those investments will not pay off soon, due to time-to-build). This shifts the marginal cost curve $C'(.)$ to the left more than the benefit of holding cash $B'(.)$ moves to the right. In that case the framework would predict that a jump in the expected long run price of the commodity is associated with a *reduction* in cash holdings, instead of an increase. This is important at the time of interpreting the effect of a jump in the long run price of copper on cash holdings, which could even go in the opposite direction to the well known effect of long term profitability on investment, which is always positive.

In our empirical setting we control for shifts in future investment opportunities using the long run price of the commodity, which helps us maintain the marginal benefit curve $B'(h)$ constant, allowing us to identify the effect of one dollar of extra cash today, so it is not about a permanently higher profitability.

Given the simple model above, our main testable prediction is as follows: *Financially constrained firms display a positive cash-flow sensitivity of cash holdings*.

A second and much more standard analysis is how current *investment* relates to cash-flows. In particular, one can adapt the same framework of Fig. 1 but relabeling the horizontal axis as investment and also relabeling the downward sloping curve as *current* investment demand by the firm, instead of future investment demand. For financially constrained firms that standard model (e.g. Fazzari et al. 1988; Kaplan and Zingales 1997a) predicts a positive cash flow sensitivity of investment (CFSI) for constrained firms; which is our additional testable proposition. Nonetheless in our setting we do not expect to find much support for it. In an industry with time-to-build current investment decisions are not made today, they were made a few years before. Moreover, the corresponding delay between decision, funding and execution is likely to be heterogeneous across firms and types of investments, making it difficult to precisely measure a relationship between investment and current or lagged cash-flows (see Section 3).

Having established our testable propositions, we now turn to a description of the institutional and technological context in which these firms operate, which will be central to our identification.

3. An industry with time to build

In this section we briefly describe the institutional context and the attributes that make this industry useful for our identification strategy. Investment in copper takes time both to be executed and to be fruitful. This is relevant for our exclusion restriction, because the NPV of an investment project is defined by the expectation of

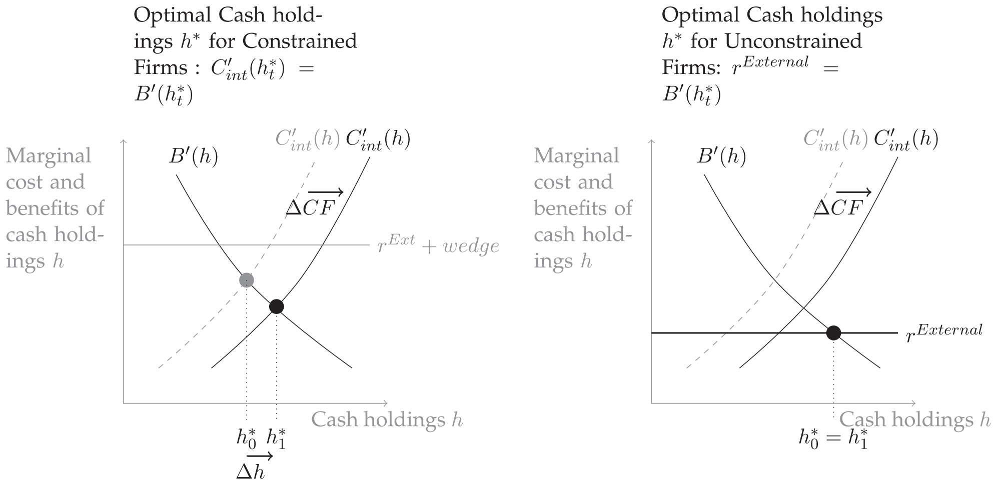

Fig. 1. Effect of an exogenous cash flow shock CF_t on optimal cash holdings h^*depending on whether the firm is financially constrained or not. Each plot depicts the internal capital market of each firm regarding the costs and benefits of holding additional cash in its balance sheet h when there is a positive shock to cash flows CF_t, which implies a shift to the right of the marginal cost of cash holdings $C'(h)$. For constrained firms there is a positive cash-flow sensitivity of cash holdings, because optimal cash flows h^*increase with an exogenous CF_t shock. In contrast, for financially unconstrained firms the relevant decision is always mediated by the intersection of the marginal benefit of holding cash and the marginal cost of obtaining cash from *external* sources $r^{External}$, not internal sources. The intersection of these two curves does *not* change when there is a shift in the internal marginal cost of cash $C'_{int}(h)$. It is important to note that the marginal benefit curve of holding cash does move when there is a shift in future investment opportunities, but only for constrained firms. In or empirical setting we aim to control for such opportunities using the long run price of the commodity, which helps keeping the marginal benefit curve $B'(h)$ constant. For unconstrained firms a jump in long run fundamentals does indeed move the future demand for investment, but unlike for constrained firms, for unconstrained firms that does not translate into a shift in marginal benefit of holding cash $B'(h)$, since resources could be financed externally so there is no additional investment option value of stockpiling cash, which is what determines $B'(h)$.

long run prices, not the spot price (see Radetzki and Van Duyne, 1984).

Copper deposits contain relatively little concentration of the metal, around half of a percentage point, with most of the rest being unwanted rock and a few byproducts. Hence, after mining there is a relevant sequence of stages performed to increase the concentration of the metal. In particular, producing copper metal has four stages: mining (which produces ores), concentrating (which produces concentrates), smelting, and refining (which produces pure copper metal). A relevant share of copper miners focus on mining ores and not on smelting, so they sell concentrates. Nevertheless, their prices are usually in contracts that are contingent to the copper price in the London Metal Exchange. Concentration of copper requires significant investments and the size of these operations usually determines the current capacity of the mine. Building these concentration plants could take one or two years even when the engineering plan is fully prepared (see Burgin, 1974; Cortazar and Casassus, 1998; Cortazar et al., 2001).

In short, if firms were theoretically informed about a transitory shock to copper prices that would last for a year or two (assuming they were 100% certain it is transitory), then there would be little margin for an investment response. These delays are, therefore, useful for our exclusion restriction, since the transitory component of spot prices should not impact current investment beyond its indirect effect on liquidity.

We are not the only researchers using copper as a lab for social science. In fact Slade (2013) tests her options model arguing that "*investment in copper mining provides an ideal laboratory in which to test the predictions of the theory of real options with time-to-build. Indeed, projects are large, prices are highly variable, investment is infrequent, and completion takes several years*". For the same reasons this setting can mitigate the endogeneity concerns that are frequent in the cash-flow sensitivity literature.

Overall, we do not presume that these results are necessarily representative of other industries. Our point is that given the various characteristics of the industry - such as lumpiness and time-to-build - if our results are not conclusive in this context, then it would be difficult to believe that these theories of dynamic cash stockpiling can have traction in other settings where the fundamentals of the business are relatively less tied to future investment options.[5]

After this description of the context we now focus on the actual construction of our dataset and later on the estimation of the cash-flow sensitivities. In the robustness checks (Sections 6–8) we will revisit this discussion to explore the validity of the instrument for cash holdings, after correcting for additional potential challenges to our identification strategy.

4. Data construction and description

4.1. Building our panel of copper mines

Using various sources we built an unbalanced panel of copper mines operating in different countries for the period 2002–2012. We selected this period given the intersection of both data availability for firms and the existence of enough relevant variation in copper prices and their long run expectations, allowing us to estimate an effect. In fact, the sample starts a few years before spot, futures and the spread of copper prices started to rise in 2004 (see Fig. 3 in the Appendix). Balance Sheet and Income Statement information is collected for each of the firms in the sample.

We built two different samples of copper firms, one with publicly traded copper companies listed in the major metal stock ex-

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[5] In this context there could be other reasons for stockpiling cash, beyond time-to-build, as we will discuss in Section 8. For example Foley et al. (2007) argue that part of the additional cash stockpiling in a large sample of US listed multinational corporations is due to tax reasons. The basic idea is that firms understand that there is a repatriation tax or withholding tax. These generate an inaction zone in which multinationals are neither repatriating dividends nor investing immediately. Faulkender and Petersen (2012) explore how changes in the American Jobs Creation Act (AJCA) significantly lowered U.S. firms' tax cost when accessing their non repatriated foreign earnings, using that as an instrument for internal cost of capital. In our data we cannot have meaningful tax variation to tell apart this taxation channel from the one of time to build, and many firms have complex structures. But the fact that we get a stronger effect of cash flow sensitivity of cash on smaller firms, which are less likely to be multinationals, suggests that the effect of taxation is less relevant than the effect of time-to-build.

changes and other with unlisted copper firms operating in countries that are currently the two largest copper producers in the world (Chile and Peru).[6] The empirical analysis below, and most importantly, our main results are robust to the use of both datasets either independently or jointly. When we use the joint sample we do not double count, in the sense that we exclude from that composite sample the multinational companies that own mines that are already counted in the sample of unlisted firms.

For publicly traded companies we relied on the definition of copper miner company from the MiningFeeds website. It outlines a list of companies mostly devoted to copper in Australia, Canada, the UK and the US. To the best of our knowledge this is the most comprehensive record of listed *copper* firms as it covers the most important metal stock exchanges. We preferred to start from an existing definition of copper companies instead of having an *ad hoc* definition. It is worth noting that many of the listed firms operate mining projects in several countries simultaneously. In terms of production, the countries in which firms in our sample operate represented almost 90% of global copper production in 2015. For example, two of the largest mining companies in our sample, BHP Billiton and Xstrata, operate in Australia, North America, South America, Africa and Asia.[7] Out of the total number of copper firms in the MiningFeeds list, we identify 35 firms with available financial statements information either in COMPUSTAT or COMPUSTAT Global database, which pass the data filters described in the next subsection.[8]

The sample of non-listed copper firms includes firms operating in Chile and Peru, two of the largest copper producers in the world. The total number of companies/mines for which we have complete information in this subsample is 18. The dataset is comprehensive for Chile as it includes all the relevant projects during the analyzed period. This dataset was hand-collected from two public sources: from 2002 to 2006, we relied on the information provided by "*Consejo Minero*", a mining association whose members are the large mining companies operating in the copper, gold, silver and molybdenum sectors in Chile. "*Consejo Minero*" collects balance sheets, income statements and production data directly from their associates, and then publishes an annual report. Our second source of information is the securities regulator (*Superintendecia de Valores y Seguros*, SVS; equivalent to the SEC in the US). By law, since 2007 MNCs operating in Chile under the DL600 foreign investors tax scheme, must report detailed financial information to SVS. It is therefore our main source of information for 2007–2012. As for Chile, for the Peruvian mines we combine data from the securities regulator and individual reports of these companies. Whenever possible we checked the consistency of the two sources in order to avoid a potential misreporting. As we will discuss later, the majority of these unlisted mines correspond to joint ventures between various companies, a behavior that is common in the copper mining industry.

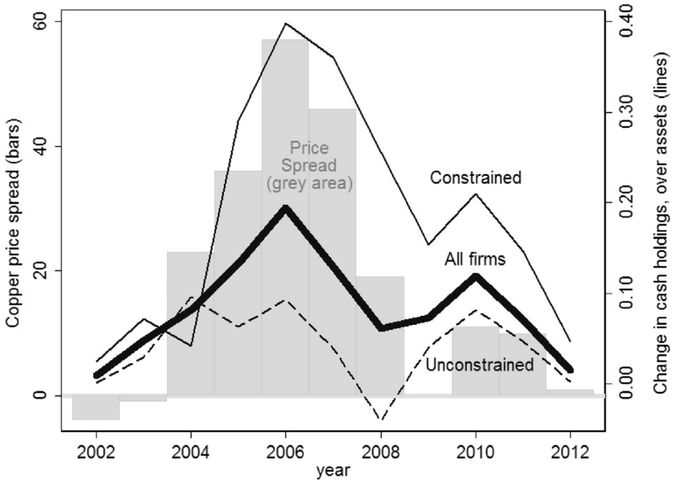

Fig. 2. Evolution of the change in cash holdings and the copper price spread over time (2002–2012). The graph displays how cash holdings in the sample changed over time, as the copper price spread changed. The three lines of changes in cash holdings are the unweighted mean across firms for the groups of financially constrained (dotted), non-financially constrained (solid) and overall sample (thick) non-financially constrained firms, according to the definition in Section 4, where the difference in cash holdings is divided by the previous year assets. The price spread is calculated as the raw difference in prices between the spot and the future. Calculations using different measures of spreads yield the same qualitative plots. We did it with spreads as fractions and also with respect to government estimates of the long run copper prices and the central trends remain robust. As complement, we run three independent time-series regressions at the aggregate level that explain the change in cash holdings. For $T=11$ periods the results indicate that a 1 cent change in the spread is associated with a 0,2 percentage points increase in $\Delta CashHoldings/Assets$ (p-value < 0.0001); while the same coefficient is more than twice as large for constrained firms (0,5 ; p-value < 0.0001) and around half and for unconstrained firms (0,1 percentage points per cent, p-value 0.015). This confirms the visual impression that the effect is stronger for financially constrained firms; even with this short time series and bootstrapped standard errors. Table 7 in the Appendix display the reduced form estimates of panel regressions that test how firm level cash stockpiling accelerates with the spread.

4.2. Definition and sources for each variable

Using the information retrieved from firms' balance sheets and income statements, and basic accounting identities, we built the variables used in the empirical analysis below. From the balance sheet, total assets (TA) are split between current assets (CA) and fixed assets (FA). Current assets are later decomposed into cash holdings (CASH) and non-cash Current Assets (non-CASH). The change in cash holdings is the main dependent variable in the analysis. We also used as a dependent variable the level of firms' investment measured as CAPEX for the sample of the listed firms and as the change in net fixed assets plus depreciation for the sample of unlisted firms. The difference in definitions is due to data availability but follows the standard. As shown in Section 8 the results are robust to changes in the definition across subsamples. We built our cash-flow measures from the income statement. Cash-flow (CF) is straightforwardly defined as earnings/losses plus depreciation. This measure of cash-flow is used to estimate both the cash-flow sensitivity of cash and the cash-flow sensitivity of investment in our baseline results. As customary, variables are scaled by total assets.

Some filters are applied to the dataset. First, as suggested by Allayannis and Mozumdar (2004) and Ağca and Mozumdar (2008), we discard from the analysis those firm-year observations with negative cash flows as these observations may distort the estimation of cash flows sensitivities. Financially distressed firms with operating losses invest differently than non distressed firms, affecting then, their sensitivities to cash flows shocks (Bhagat et al., 2005). For example, the inclusion of negative cash flows obser-

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[6] The original version of this article was completed with the sample of unlisted copper firms. Later, and in order to check the robustness of our results and to avoid small size problems in our econometric exercises, we built a larger sample of publicly listed firms. We thank the Editor and the referees for suggesting this extension in dataset.

[7] BHP Billiton operates copper mines in Australia, Chile and Perú, whereas Xstrata operates in Australia, Philippines, Malaysia, US, Chile, Perú, Congo and Zambia. Publicly listed firms in our sample have mining operations in 30 countries: Australia, Azerbaijan, Brazil, Canada, Congo, China, Colombia, Finland, India, Indonesia, Ireland, Laos, Libya, Mauritania, Mexico, Mongolia, Mozambique, Namibia, New Guinea, Pakistan, Peru, Poland, Portugal, Spain, Sweden, South Africa, Tanzania, Turkey, US and Zambia.

[8] This sample includes 17 Australian companies, 12 Canadian companies, 2 US companies and 4 UK companies.

vations would explain why some previous empirical studies (e.g. Cleary, 1999) find that the cash-flow sensitivity of investment is not significant for financially constrained firms although it is significant for financially unconstrained firms. Second, we discard firm-year observations in which some sanity checks on accounting identities are violated (e.g. a ratio of current assets over total assets larger than 1). Finally, we winsorize the data excluding observations below the percentile 1 and above the percentile 99. Our final sample contains approximately 350 firm-year observations.

Guided by previous literature and data availability we define a set of control variables to be included in our estimations. Our first control is size measured as the logarithm of total assets. A second standard control is leverage, defined as the ratio of total liabilities and total assets. Considering that the instrument used to identify exogenous variation in cash flows is the spread between the future and the spot copper price, we add as a control the 3-year US T-bill interest rate in order to avoid the identified effect being simply due to a mechanical relation between the spot-future differential and the interest rate. As a robustness check we later add two macroeconomic variables that account for time-varying effects beyond the one captured by changes in the 3-year interest rate: Chinese GDP growth and an index of metal commodity prices, from both from the IMF. The Chinese economy is the largest consumer of raw copper in the world and its GDP growth rate is a good proxy of the world demand for the metal (e.g. Ahuja and Nabar, 2012). Using Bloomberg we built a credit rating dummy that takes the value of 1 if the firm has a credit rating stamp from any of the big three rating companies (S&P, Fitch and Moodyś) or by Bloomberg itself, and 0 otherwise. In the robustness section, we include the Tobinś Q as a proxy of the future investment opportunity set for the subgroup of publicly listed firms in the sample.

Additionally, we collect spot and future market prices of copper from Bloomberg . In particular, the spot price corresponds to the annual average of the weekly spot copper prices in the London Metal Exchange, and the future prices is the 27-month rolling forward copper price at the London Metal Exchange. In some specifications we include them as control variables while in others we build a spread (spot price – future price) that we use in our IV estimations. Fig. 3 in the Appendix shows the time-series of the spot and future price of copper from 2000 to 2013, as well as the spot-minus-future spread for the same time span. The spread shows considerable swings through time, providing enough variation to shift cash-flows as we will see in Section 5. Finally, one could argue that long run expectations might be better proxied by industry experts that are thinking at longer horizons, for example 10 years, which exceeds the forward market. Since each firm's estimations of long run prices are in fact a corporate secret for mining companies, in a robustness check we use the long run price expectations made by a panel of experts in Chile. Namely the "*Comité Consultivo del Precio de Referencia del Cobre*", compiled by the Chilean Budget Office. These expert opinions are winsorized and averaged, serving each year as input for the fiscal planning in Chile (see Frankel, 2011). Finally, using the dispersion in the price forecasts provided by the members of the panel of experts, we compute the yearly coefficient of variation of the pricEś forecasts and we use it as our proxy of expected cash-flow risk. As a robustness check, we also built the coefficient of variation across different analysts using yearly long-run copper price forecasts from a set of investment banks available on Bloomberg. Both methods yield qualitatively similar results.

4.3. Descriptive statistics for main variables of interest

Table 1 reports the descriptive statistics of the main variables. They are reported as percentages, scaled by current total assets, although in the regression we use lagged assets, as customary. The stock of cash holdings is on average 13% of assets, but with relevant variance over time, as we will discuss later. Current assets, which also include non-Cash components like inventories and receivables, represent a third of total assets, with the remaining two thirds of total assets corresponding to fixed assets.

When we look at these variables as flows, we observe that changes in cash holdings represented 7% of total assets, while changes in current assets were 23% of total assets. The average investment was 18% of total assets. The volatility of investment, measured by its standard deviation, is relatively large (32%), as expected from models of lumpy investment. Cash flows for these companies are important, averaging a 30% of total assets, with a volatility level of 27%. Regarding other control variables, the average firm' s leverage in our sample is approximately 35% of assets.

The price boom was the main development in the copper industry during this extended decade (see Fig. 3 in the Appendix). This appears to have an effect on the average balance sheet of firms, since they not only expanded in size but also their share of cash over total assets doubled or even tripled (see Online Appendix for the full time series). At the beginning of our sample period, when copper prices were almost $1 a pound, cash holdings were approximately 6% of assets. As the copper price increased significantly above $3 per pound, the share of cash became up to 21% of the balance sheets. In relative terms our sample of mines stockpiled more cash than average firms in the US stock market.[9] Mining became relatively more cash intensive and the remainder of this paper explores whether this is related to cash-flow sensitivity.

As a preliminary evidence Fig. 2 shows that even in the raw time series the change of cash holdings relate to the spread in copper prices. The two series comove. When the price spread rose, depicted as grey bars, then the cash holdings accelerated, as shown by the thick line. It is clear from the plot that the effect was stronger for financially constrained firms (solid line), with twice as much acceleration in cash holdings for a given increase in the spread (p-value < 0.05). The rest of the paper explores in greater detail this trend that is already apparent in Fig. 2.

5. Estimating the basic cash-flow sensitivities

We study the impact of cash-flows shocks on cash holdings and investment using the baseline instrumental variables model defined by the system of Eq. (1) , in which cash-flows $CF_{i,\,t}$ are instrumented by the spread z_t, as shown below:

$$\begin{aligned} \text{[IV-2nd Stage]}: \quad & y_{i,t} = \beta \hat{CF}_{i,t} + \gamma_1 P_t^{Long} + \gamma_2 X_{i,t-1} + \mu_i + u_{i,t} \\ \text{[IV-1st Stage]}: \quad & CF_{i,t} = \eta z_t + \phi_1 P_t^{Long} + \phi_2 X_{i,t-1} + \widetilde{\mu}_i + \varepsilon_{i,t}; \end{aligned} \tag{1}$$

where $y_{i,\,t}$ is either investment or the change in cash holdings of the company i in year t, depending on the selected specification. The estimated IV coefficient β measures the cash flow sensitivity of $y_{i,\,t}$ (i.e. CFSI when $y_{i,\,t}$ is investment; while CFSC when $y_{i,\,t}$ is change in cash holdings). As a central control we include the logarithm of the expectation for the copper price in the long run (P_t^{Long}) in order to control for changes in the future investment opportunity set. Instead of Tobin' s Q, as it is common in the literature, we have the crucial advantage of observing one of the most important fundamentals that determine investment: proxies for the expectations of long term prices (in Section 7 we also included Tobin's Q).

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[9] A table with the detailed asset composition by year is available in the Online Appendix. As a matter of benchmarking, Campello (2015) shows that in the years before 2000 firms in the S&P 500 held around 6% of assets in cash or liquid instruments, very similar to our initial conditions; but between 2004 and 2014 S&P 500 firms were holding around 10% of their balance sheets in cash. As mentioned, firms in copper have a share of cash above 20% of the balance sheet, so these firms seemed to be stockpiling relatively more cash.

Table 1
Descriptive statistics.

	Obs.	Mean	Std. dev.	Min	p25	p50	p75	Max.
Stock variables								
cash	350	0.13	0.15	0.00	0.02	0.07	0.18	0.74
Current assets	350	0.33	0.19	0.02	0.18	0.28	0.42	0.88
Fixed assets	350	0.68	0.19	0.12	0.58	0.72	0.82	0.98
Flow variables								
ΔCash	350	0.07	0.22	−0.54	−0.06	0.00	0.13	1.15
ΔCurrent assets	338	0.23	0.21	−0.13	0.12	0.24	0.44	0.94
ΔFixed assets	350	0.18	0.32	0.00	0.05	0.11	0.23	4.79
Cash flow	350	0.30	0.27	0.00	0.10	0.19	0.34	1.29
Other controls								
Size	350	2.05	1.75	−2.16	1.01	2.12	3.22	4.73
Leverage	350	0.35	0.21	0.01	0.06	0.21	0.43	1.16
Tobin's q	274	1.60	1.29	0.13	0.76	1.27	2.04	9.66
Copper spot price	350	2.75	1.04	0.71	1.59	3.12	3.43	4.00
Copper future price	350	2.58	1.04	0.75	1.24	2.77	3.38	3.90
LT copper price (gov)	332	1.82	0.82	0.88	0.99	1.99	2.65	3.12
Credit rating dummy	350	0.58	0.49	0.00	0.00	0.00	1.00	1.00
3-year interest rate (%, $)	350	2.17	1.49	0.38	0.75	1.43	3.93	4.77
China GDP growth rate (%)	330	10.28	1.77	7.79	9.22	9.63	10.33	14.16
Commodity index (metals)	350	156	52	53	108	177	192	234
Cash-flow risk I (Coef. of var.)	348	0.09	0.04	0.02	0.06	0.09	0.10	0.16
Cash-flow risk II (Coef. of var.)	348	0.12	0.04	0.06	0.90	0.11	0.14	0.20

The table shows descriptive statistics for the main variables in the analysis covering the period 2001–2012. Stock and Flows variables are standard Balance Sheet and Income Statement variables obtained from Compustat and Compustat Global for the sample of publicly listed firms and from the Regulatory Securities Agencies in Chile and Peru for the sample of unlisted firms. Size is the demeaned natural logarithm of total assets and leverage is the ratio of total debt to lagged total assets. From Bloomberg, we obtained information about the copper spot price and the 27-month forward copper price from the London Metal Exchange. LT Copper Price (gov) is a 10-year forecasted copper price produced by an expert committee of the Chilean Budget Office and available online at its webpage. Prices are measured in US$/lb. Credit rating dummy is variable that takes the value of 1 if the firm is non-rated by any of the three big credit rating agencies in 2014 and 0 otherwise. We obtain the credit rating information from Bloomberg. The 3-year US Treasury constant maturity rate is the yield on U.S. Treasury securities at 3-year with constant maturity. This series is retrieved from the Federal Reserve Economic Data (FRED) available at the Federal Reserve Bank of St. Louis' website. The GDP growth rate of China and the Commodity Index for metals were obtained the IMF' s International Finance Statistics and the IMF Primary Commodity Prices dataset, respectively. Cash-flow risk is proxied by the coefficient of variation of the LT Copper price's forecasts. The first cash-flow risk measure uses forecasts produced by the aforementioned panel of experts from the Chilean Budget Office and the second one uses forecasts produced for several investment banks and professional forecasting agencies. Stock and flow variables, as well as the debt variables are scaled by total assets.

Finally, $X_{i,t-1}$ is a set of additional control variables that can potentially vary by firm and year, for example size and leverage. In some specifications we include additional time-varying controls. Notably, all specifications include a firm fixed effect μ_i, aiming to correct for time-invariant unobserved heterogeneity. Finally, $u_{i,\,t}$ is an unobserved random error term which is clustered at the firm level.

Thus, our main model in Eq. (1) is a standard instrumental variables fixed effects (IV-FE) model. It is important to recall that the equation already controls for the expectations of long run price.[10] In short, we argue that the instrumented coefficient β indicates the effect of a shift in the marginal costs of funds without changing the marginal benefits outlined in Section 2.

We correct for the risk free interest rate in dollars for the same duration of the forward, which is done in all groups of specifications. Therefore we are implicitly including the convenience yield in the instrumented regression (i.e. spot minus forward minus interest rates), although in a more flexible manner. Additionally, our specifications implicitly include all three underlying factors for commodity pricing described in Casassus and Collin-Dufresne (2005) , but with the advantage of allowing price and interest rate to also appear in the second stage regression.[11] In the robustness checks we also use some other fundamentals that could potentially be related to time-varying factors impacting commodities, like the Chinese growth rate (see Ahuja and Nabar, 2012). In some specifications, controlling for leverage also helps us explore whether it is borrowing rather than own-cash-savings which generates the additional stockpiling of liquidity. Controlling simultaneously for long term prices and leverage mitigates the potential two-way causality between long term profitability and leverage, which is common in the cash-flow sensitivity literature (e.g. Almeida and Campello, 2010). For our empirical strategy this might be less relevant since long term profitability, which impacts the value of mines and its

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[10] We argue that this identification strategy is valid since the instrument z_t (spread) can contemporaneously affect cash flows without necessarily affecting the level of investment of the firms. In other words, once controlling for long run profitability due to future prices, the instrument can move the supply curve of cash for internal projects in the firm without moving the set of investment opportunities and without moving the marginal benefits of stockpiling cash due to options of future investment. The IV estimates aim to capture *current* effects between cash flow and cash holdings and investment. For robustness, some specifications incorporate a single lagged level of the dependent variable, trying to address the persistence concerns in Gatchev et al. (2010), but constrained by the context of our smaller T study. Rather than doing something with more lags and structure, we prefer to focus on the current effects, which are certainly not the whole story of cash stockpiling, but this is what we can attempt to identify given our shock. In the robustness check section we explore how current cash flows may impact future investment.

[11] Because we are using forward or long run prices as a control, we implicitly allow for a more flexible parametrization between this convenience yield and the prices. Some asset pricing models tend to assume away potentially time varying risk premia by assuming that traders are fully hedged in their positions and therefore face no risk. That is not always true for producers (as argued by Acharya et al., 2013), which have meaningful non hedged exposures to the commodity. This is important because if they were fully hedged there would be no impact of the surprising portion of the spot prices on cash flows. In econometric terms there would be no significant first stage, which we actually have. Also, in conversations with managers in the industry we realized that as much as 60–80% of the production of some mines is sold in advance, but many times at prices that are defined as a spread over the London Metal Exchange price (LME), meaning that even if the deals are closed in advance, the mines continue to have a meaningful exposure to LME price fluctuation, consistent with our first stage results. Nevertheless, our approach is to recognize there might be some other factors moving over time and we aim to control them in regressions using a various time-varying covariates.

Table 2
Baseline regressions.

	(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	1st stage (lhs: CF)	ΔCash holdings					Investment				
CF	–	0.345***	0.302***	0.236***	0.306***	0.388***	0.302	0.0382	-0.0563	0.0132	-0.0254
		(0.0772)	(0.0927)	(0.0916)	(0.0955)	(0.117)	(0.190)	(0.157)	(0.188)	(0.138)	(0.164)
LT Copper Price	0.185***	−0.0653***	−0.0627***	0.103	0.0919	0.00616	−0.0519	−0.0486	0.234*	0.223**	0.253**
	(0.0393)	(0.0158)	(0.0159)	(0.0788)	(0.0820)	(0.0310)	(0.0462)	(0.0492)	(0.124)	(0.113)	(0.124)
Size	−0.139***			−0.183**	−0.187**	−0.0928***			−0.350**	−0.352**	−0.376**
	(0.0480)			(0.0903)	(0.0927)	(0.0297)			(0.174)	(0.173)	(0.191)
Leverage	0.0298			−0.107	−0.0950	−0.00839			−0.456**	−0.444***	−0.437**
	(0.0675)			(0.0998)	(0.103)	(0.0805)			(0.178)	(0.171)	(0.179)
Interest Rate	−0.0260**				−0.0171*	−0.0285***				−0.0166	−0.0274*
	(0.0113)				(0.00947)	(0.0101)				(0.0171)	(0.0161)
Lagged Dep. Var.						−0.0236					0.0406
						(0.0144)					(0.0452)
Spread (z)	0.399***										
	(0.0401)										
Obs.	350	366	347	347	347	316	366	341	341	341	310
R^2	0.510	0.121	0.117	0.226	0.228	0.230	0.063	0.020	0.297	0.310	0.334
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test			50.75	29.74	25.51	22.58		50.77	30.75	27.44	20.80
Method	OLS	OLS	IV	IV	IV	IV	OLS	IV	IV	IV	IV

Note: The table presents panel regression estimates of $y_{it} = \beta CF_{it} + \gamma_1 LTCopperPrice_{t-1} + \gamma_2 X_{it-1} + \mu_i + \varepsilon_{it}$; where y_{it} is either $\Delta Cash\,Holdings_t$ (specifications 1–5) or $CAPEX_t$ (specifications 6–10). CF_t is cash flow in *t*, *LTCopperPrice* is the 27-month forward copper price, *Size* is the demeaned natural logarithm of total assets, *Leverage* is the ratio of total debt to lagged total assets, *InterestRate* is the 3-year US Treasury constant maturity rate and Lagged Dep. Var. is the lagged dependent variable. In the IV estimation method, $CF_t$is instrumented with the spread between the spot copper price and the forward copper price, *Spread*. In column (0), the estimated IV's first stage is reported. Note that for this column the left-hand size (lhs) variable is firm's Cash Flow. Robust standard errors clustered by firm in parenthesis: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

pledge-able income to obtain more leverage, has been econometrically isolated from the current transitory component of cash. It is reassuring that our basic results regarding cash stockpiling remain robust to these various changes.

5.1. Main cash flow sensitivities

Our basic results are displayed in Table 2. Column (1) estimates a benchmark bivariate OLS with a cash flow sensitivity for cash holdings (CFSC) of 0.34, meaning that when cash flows change by a dollar, cash holdings change by 34 cents. Columns (2)–(5) display IV estimates showing sensitivities between 0.23 and 0.39, depending on the set of controls. These magnitudes are robust across specifications and not substantially different from the raw OLS estimates in column (1). In fact the confidence intervals overlap between the various IV and the OLS. In contrast, for investment cash flow sensitivities (CFSI) we find that all specifications (6)–(10) are statistically indistinguishable from zero.

Column (0) reports the IVś first-stage regression in order to confirm that our instrument predicts cash flows, over and above the potential effect of the long run price of copper. This first stage, which corresponds to the IV of our preferred specification (4) and (8), shows that the spread is highly predictive of firmś cash flows (F-test > 25). The corresponding reduced form estimations are also statistically significant (Table 7 in the Appendix). Overall, the first-stage is consistent with our identification strategy, separating the temporary cash flow shocks from the long-run investment opportunities.

Some estimates besides cash flow sensitivities seem reassuring of our method. Firstly, after controlling for size and leverage, our investment regressions show that the long run price of copper is statistically significant. This is our equivalent of Tobin's Q and one of the main drivers of the narrative of investment in our paper. In contrast, one has to be clear that due to time-to-build and other economic considerations the sign of the long run copper price in the cash regressions is not obvious ex-ante, and could be context dependent, without invalidating our identification assumptions. In fact some seminal papers estimating CFSC have statistical zeroes on the role of Tobin's Q (e.g. Almeida et al., 2004). Another reassuring result is that the coefficient on the size of the company has a negative and statistically significant coefficient in the regressions for cash holdings and investment, consistent with previous literature. Additionally, the interest rate displays a negative and statistically significant coefficient in specification (4) and (5), consistent with the view that the interest rate increases the opportunity cost of holding cash. Although this is less robust over specifications, in the majority of cases one obtains a negative point estimate for the interest rate on cash and investment, as expected. Columns (3)–(5) also correct for leverage finding negative but insignificant point estimates in cash holdings, while for investment regressions (8)–(10) the results are significant: as firms become more indebted they invest less.

Most studies of cash flow sensitivity of cash holdings do not include lags. However, a few exceptions attempt this correction, namely Gatchev et al. (2010) and Dasgupta et al. (2011). Our goal of including some lags in specifications (5) and (10) is simply checking the sensitivity of our main results to some basic concerns about persistence. Most of the studies that include a lag tend to have large panels of COMPUSTAT data or equivalent, which is very different from our sample. Therefore our goal is not to presume that we are obtaining all the correct dynamics , but to check whether cash flow sensitivities are robust to the inclusion or omission of some basic lagged dependent variables. Our central results are in fact unchanged.

Overall, our results support the view that on average between a quarter and a third of these transitory cash flows are stockpiled, while no statistically significant result is found in terms of current investment. As discussed in Section 2, this behavior of positive CFSC and noisy CFSI is reasonable to expect in a context of time-to-build, because investment decisions need long horizons for planning and execution; while cash holdings do not have this time-to-build problem.

5.2. Estimating the additional cash flow sensitivity of financially constrained firms

As usual in this literature we now explore whether the cash flow sensitivities become stronger for firms that are likely to be more financially constrained, as suggested in the framework of

Table 3
Baseline with interaction for small / financially restricted firms.

	(0) 1st stage	(1) Δ Cash holdings	(2)	(3)	(4)	(5)	(6) Investment	(7)	(8)	(9)	(10)
CF	–	0.237^{***}	0.140^{*}	0.0695	0.141^{**}	0.197^{**}	0.0658^{*}	0.112^{**}	−0.0472	0.0215	0.0670
		(0.0699)	(0.0730)	(0.0676)	(0.0670)	(0.0859)	(0.0400)	(0.0563)	(0.128)	(0.103)	(0.0990)
CF × Small	–	0.360^{**}	0.796^{**}	0.873^{***}	0.868^{***}	0.870^{**}	0.737	−0.373	−0.147	−0.142	−0.493
		(0.181)	(0.315)	(0.310)	(0.316)	(0.340)	(0.470)	(0.726)	(0.507)	(0.503)	(0.485)
Small	0.161^{***}	0.0630	−0.0161	−0.128	−0.119	-0.233^{*}	-0.243^{**}	0.110	−0.124	−0.120	−0.0115
	(0.0494)	(0.132)	(0.179)	(0.118)	(0.119)	(0.123)	(0.122)	(0.261)	(0.166)	(0.168)	(0.174)
LT Copper Price	0.0372	-0.0374^{*}	−0.0199	0.0962	0.0864	−0.00236	−0.0421	−0.0539	0.237^{*}	0.226^{*}	0.262^{*}
	(0.0326)	(0.0203)	(0.0282)	(0.0805)	(0.0827)	(0.0312)	(0.0356)	(0.0553)	(0.129)	(0.119)	(0.139)
Size	−0.0556			−0.143	−0.146	−0.0608			-0.381^{*}	-0.382^{*}	-0.419^{*}
	(0.0456)			(0.0914)	(0.0944)	(0.0513)			(0.199)	(0.196)	(0.229)
Leverage	−0.0624			−0.0790	−0.0662	0.0658			-0.436^{**}	-0.422^{**}	-0.425^{**}
	(0.0405)			(0.116)	(0.121)	(0.0887)			(0.179)	(0.170)	(0.177)
Interest Rate	−0.0029				−0.0168	-0.0240^{**}				−0.0162	-0.0317^{*}
	(0.0102)				(0.0109)	(0.0118)				(0.0166)	(0.0179)
Lagged Dep. Var.						-0.0354^{**}					0.0360
						(0.0167)					(0.0467)
Spread (z)	−0.0062										
	(0.0171)										
Spread × Small	0.303^{***}										
	(0.0808)										
Obs.	346	366	346	346	346	316	366	340	340	340	310
R^2	0.448	0.174	0.135	0.188	0.180	0.210	0.135	−0.081	0.278	0.294	0.260
Firm-FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test			27.98	21.72	20.42	17.97		28.06	22.27	21.30	17.00
Method	OLS-FS	OLS	IV	IV	IV	IV	OLS	IV	IV	IV	IV

Note: The table presents panel regression estimates of Eq. (2) where $y_{it} = \beta\, CF_{i,t} + \beta_{small}\, CF_{i,t} \times small_i + \gamma_1 P_t^{Long} + \gamma_2 X_{i,t-1} + \mu_i + u_{i,t}$; with y_{it} being $\Delta Cash\,Holdings_t$ (specifications 1–5) or $CAPEX_t$ (specifications 6–10). CF_t is cash flow in *t*, *Small* is a dummy variable that takes the value of 1 if the firm belongs to the three lower deciles according to the firm's size, *LTCopperPrice* is 27-month forward copper price, *Size* is the demeaned natural logarithm of total assets, *Leverage* is the ratio of total debt to lagged total assets, *InterestRate* is the 3-year US Treasury constant maturity rate and Lagged Dep. Var. is the lagged dependent variable. $CF_t$and *CF* × *Small* are instrumented with the spread between the spot copper price and the forward copper price, *spread*, and *spread* × *Small*, respectively. In column (0), the estimated IV's first stage is reported (OLS-FS). Note that there are two instruments and therefore the estimation has two equations for the IV's first stage. For space reasons in column (0) we only report the one in which the left-hand size (lhs) variable is *CashFlow* × *Small*. Clustered-by-firm robust standard errors in parenthesis: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Section 2. In particular, we estimate the IV system of Eq. (2) below:

$$\begin{aligned}&[\text{IV-2nd Stage}] \quad y_{i,t} = \beta\, CF_{i,t} + \beta_{small}\, CF_{i,t} \times small_i + \gamma_1 P_t^{Long} \\ &\quad + \gamma_2 X_{i,t-1} + \mu_i + u_{i,t} \\ &[\text{IV-1st Stage}] \quad CF_{i,t} = \eta z_t + \eta_{small}\, z_t \times small_i + \phi_1 P_t^{Long} + \phi_2 X_{i,t-1} \\ &\quad + \tilde{\mu}_i + \varepsilon_{i,t}; \qquad (2)\end{aligned}$$

where the new term is the interaction between cash flows and a dummy variable $small_i$ takes the value one if firm's assets are in the lowest tercile of size distribution, as usual in the literature (e.g. Almeida et al., 2004).[12] In this context the coefficient β_{small} represents the additional cash flow sensitivity of financially constrained firms.[13]

Table 3 shows the results. The estimates of β_{small} for cash holdings are in general positive and statistically significant, meaning that the CFSC is stronger for financially constrained firms as shown in columns (1)–(5). While the point estimates here are much higher than in the basic regressions of Table 3, the confidence intervals in these specifications is also wider and in all cases they include the 30–40 cents on the dollar previously estimated . Column (0) reports the IVś first stage regression results to confirm that our instrument is in fact predictive when included as interaction. The term (spread × small) is positive and statistically significant, suggesting that our instrument hits precisely among constrained firms.

In contrast, the investment regressions in columns (6)–(10) display a $\hat{\beta}_{small}$ that is statistically indistinguishable from zero in all IV specifications. Again, as predicted, the long run price of copper is positive and significant for investment. In the robustness check section we attempt other ways to define financially constrained firms and obtain similar results. In previous versions of the paper, instead of running interactions, we included regressions within the subset of financially constrained firms and also obtained stronger estimates for the CFSC, with mostly insignificant results for CFSI. We preferred the interactions since we can directly test whether there is a larger coefficient for these smaller firms and also maintain more power.

6. Potential concerns about identification.

Our argument is that, after controlling for shifts in future investment opportunities, stockpiling of cash is related to financial constraints. But there can be alternative stories that could potentially challenge our identification. Our strategy would be to review several of these channels in the literature and test their implications (see Opler et al., 1999; Amess et al., 2015; Lins et al., 2010; Demiroglu and James, 2011). The most basic concern in the literature focuses on the interest rate, which is already included as control in our main specifications in Section 5. Correcting for the inter-

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[12] Studies that define financially constrained firms as those in the lowest tercile of size consider the whole distribution of COMPUSTAT firms and not a single subindustry, as we are doing here. However, the average of our sample is not very different from COMPUSTAT's. Ulbricht and Weiner (2005) reports that average and median assets in COMPUSTAT North America are \$5210 million and \$160 million respectively. For our sample the mean is \$4590 and the median \$90 million. In natural log terms the difference in medians is less than 0.5, which is only equivalent to a few percentiles difference in the distribution of COMPUSTAT. In any case, using a cutoff similar to that implied by COMPUSTAT does not change our main results.

[13] While in the robustness sections we use an alternative measure of financial constraints, we started with size because we did not want to use the listed / unlisted status. It turns out that massive operations like *Escondida* mine - the largest copper mine in the world - are not directly listed and in the majority of cases (67%) they correspond to joint ventures of various listed companies, with some of the firms helping in project finance. Therefore it is less clear that the unlisted sample is more financially constrained. In that sense we preferred maintaining size as an indicator of constraints.

Table 4
Robustness to identification concerns and to investment opportunity set mismeasurement.

	(1) Non-cash component of CA	(2) Cash flow uncertainty I	(3)	(4) Cash flow uncertainty II	(5)	(6) Publicly listed sample with LT price & Tobinś Q	(7)	(8) Erickson–Whited GMM full sample	(9)
	ΔCA-ΔCash	ΔCash	Inv.	ΔCash	Inv.	ΔCash	Inv.	ΔCash	Inv.
	Panel (a) Homogeneous effect								
CF	0.121	0.429***	−0.0473	0.402***	−0.0499	0.568***	0.0101	0.351*	−0.0401
	(0.147)	(0.136)	(0.164)	(0.133)	(0.170)	(0.209)	(0.413)	(0.183)	(0.201)
LT Copper Price						0.0290	0.296*	0.587**	0.292
						(0.0373)	(0.158)	(0.241)	(0.223)
Q-Tobin						0.00144	0.0157		
						(0.0114)	(0.0142)		
	Panel (b) Heterogeneous effect for small/financially constrained firms								
CF	0.123	0.230**	−0.120	0.200**	−0.0342	0.226*	0.190	0.185	0.0556
	(0.0965)	(0.101)	(0.536)	(0.100)	(0.135)	(0.124)	(0.318)	(0.300)	(0.138)
CF × Small	−0.0856	0.956***	−0.0397	0.955***	−0.128	0.652**	−0.280	0.547	−0.299
	(0.435)	(0.369)	(0.122)	(0.362)	(0.530)	(0.310)	(0.543)	(0.604)	(0.357)
LT Copper Price						0.0114	0.305*	1.791***	0.123
						(0.0431)	(0.176)	(0.366)	(0.115)
Q-Tobin						0.00124	0.0190		
						(0.0115)	(0.0130)		
Obs.	347	327	322	327	322	238	240	350	350
Method	IV	IV	IV	IV	IV	IV	IV	GMM	GMM

Note: In this table we estimate several alternative specifications dealing with potential concerns with identification and measurement issues of the investment opportunity set in the model. In particular, we re-estimate specifications (4) and (9) in Tables 2 and 3. In panel (a), the estimated cash-flow sensitivities of cash (CFSC) and investment (CFSI) coefficients (β) in specifications (3) and (7) in Table 2 are reported, and in panel (b), the estimated CFSC and CFSI coefficients ($\hat{\gamma}_1$) and its interaction with a Small/financially constrained dummy variable (β_{small}) in specifications (4) and (9) in Table 3are reported. We also report estimates of the LT Copper price and Tobinś Q when required. At the top of each column, a label indicating the specific robustness check applied is shown. In column (1), we estimate the cash-flow sensitivities to the non-cash component of current assets (CA), defined as the change in Current Assets minus the change in Cash Holdings. In columns (2)–(5), we estimate CFSC and CFSI including as an additional control variable a proxy of cash-flow risk, namely, the coefficient of variation of the forecasts for LT Copper price. In columns (2) and (3), the forecasts are produced by a panel of experts from the Chilean Budget Office, whereas in columns (4) and (5), the forecasts are produced by several investment banks and professional forecasting agencies. In columns (6) and (7), both the LT copper price and the Tobinś Q, measured as the book value of debt plus market capitalization divided by the book value of assets, are included as control variables simultaneously. In columns (8) and (9), we report Erickson and Whited (2000)ś GMM estimator accounting for measurement error in the LT copper price. $CF_t$and $CF \times Small$ are instrumented with the spread between the spot and the forward copper prices, *spread*, and *spread* × *Small*, respectively. Except by estimates in columns (8) and (9), clustered-by-firm robust standard errors are reported in parenthesis: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The Online Appendix displays the full list of coefficients for specifications of columns (2)–(5).

est rate leaves little opportunity for a direct impact of the spread between long run and spot price. A second alternative channel to increase cash holdings is the cost of raising funds through asset sales, dividend cuts and renegotiation. Nevertheless, the market value of non-cash assets in this industry might be connected to the expectations of long run price of copper, and not to the spread. In that sense, both the firm fixed effect and the long run price of copper are likely to be the main channel, leaving little opportunity for the spread between short and long run price to enter directly into optimal cash holdings, beyond its effects on cash flows (i.e. the exclusion restriction). A third alternative channel could be that the spread impacts the costs of hedging instruments. However, they are likely to be similar for all firms, after correcting for time-invariant firm characteristics and size. In some specifications we also include a time-varying industry volatility and our main results remain robust to this inclusion. A fourth potential challenge would be if the cash-conversion cycle becomes longer with our instrument. If a company used to need one month to transform accounts receivable into cash and now it needs two months, then the need for optimal cash holdings may increase. However, various reasons suggest that an exogenous shift in our instrument - the spot minus long run price - may not be causing this delay in payments. At the most basic level we are already controlling for the company assets over time and various other time-varying controls. Most importantly, if the cash conversion cycle increases one would expect the non-cash component of current assets to also increase. Nonetheless Column (1) in Table 4 shows that the non-cash component of the balance sheet is not systematically related to the instrumented cash flow changes. The effect seems to be on the cash component. Importantly, conversations with these companies' CFOs suggest that there are long term contracts that define the method, timing, and conditions of payment; so the length of the cash-conversion cycle is unlikely to change at the frequency of our instrument for cash flow. A fifth alternative channel to stockpile liquidity would be jumps in the expected cash flow uncertainty. So far the literature tends to use an “industry sigma” to account for the volatility of cash flows (e.g. Cleary, 1999). In our case we are working with a single industry and firm fixed effects, so the concern for cross-sectional variation in cash flow volatility seems less relevant. Nevertheless, one can still think that there is some time variation in cash flow uncertainty. To proxy for this Table 4 controls for two proxies of the cross-sectional disagreement of copper price forecasts among analysts each year, representing a time-varying belief of future cash flow uncertainty. Columns (2) and (3) use the cross sectional variance among fiscal advisers of the Chilean Budget Office regarding their 10 year projections; while Columns (4) and (5) use the cross sectional variance of long run copper price estimates by leading investment banks and professional forecasting agencies reported in Bloomberg. Neither test changes our central conclusions, suggesting that our stockpiling results may not be due to shifts in uncertainty. A sixth reason might be transaction costs in raising outside funds and in cash management, but our main specifications already control for both the size of the company and a fixed effect by firm; which in principle capture these economies of scale.

Summing up, the main challenges to our identification strategy do not seem to be supported by the additional evidence provided. Finally, as a matter of magnitude, in Section 4 we already remarked that there was up to a tripling of the cash holdings in these companies, beyond the trend observed for S&P 500 companies. An effect of such magnitude seems unlikely to be explained simply by marginal changes in incentives to hold more cash for the reasons discussed above. There are reasons to interpret cash flow sensitiv-

Table 5
Sub-sample analysis and additional robustness tests.

	(1) Differences listed vs. unlisted	(2)	(3) Alternative LT copper price	(4)	(5) Credit rating as restricted criteria	(6)	(7) Bootstrapped stand. errors	(8)
	ΔCash	Inv.	ΔCash	Inv.	ΔCash	Inv.	ΔCash	Inv.
	Panel (a) Homogeneous effect							
CF	0.210^{***}	−0.0611	0.196	−0.0683	0.306^{***}	0.0132	0.315^{***}	−0.009
	(0.0781)	(0.0779)	(0.208)	(0.0840)	(0.0955)	(0.138)	(0.121)	(0.149)
	Panel (b) Heterogeneous effect for small/financially constrained firms							
CF	0.106	−0.0471	0.0494	−0.135	0.168^{**}	−0.0324	0.045	−0.006
	(0.0709)	(0.0781)	(0.153)	(0.111)	(0.0759)	(0.0948)	(0.125)	(0.103)
CF × Small	0.718^{***}	−0.231	0.692^{*}	0.343	0.680^{***}	0.221	1.317^{**}	−0.141
	(0.254)	(0.159)	(0.372)	(0.444)	(0.242)	(0.430)	(0.596)	(0.648)
Obs.	346	340	303	298	347	341	347	347
Method	IV	IV	IV	IV	IV	IV	IV	IV

Note: In the table we report estimates dealing with firm heterogeneity (listed vs. unlisted) and a set of additional robustness tests. In particular, we re-estimate specifications (4) and (9) in Tables 2 and 3. In panel (a), the estimated cash-flow sensitivities of cash (CFSC) and investment (CFSI) coefficients (β) in specifications (4) and (9) in Table 2 are reported, and in panel (b), the estimated CFSC and CFSI coefficients (β) and its interaction with a Small/financially constrained dummy variable (β_{small}) in specifications (4) and (9) in Table 3are reported. At the top of each column, a label indicating the specific robustness check applied is shown. In columns (1) and (2), the baseline specifications are extended by including several interaction variables between the main variables and a publicly listed dummy in order to account for any differential effect between listed and unlisted firms in our sample. In columns (3) and (4), we check the robustness of the baseline results to an alternative long-term copper price by replacing the 27-month future copper price by a long-run (10 year) copper price forecast provided by the an expert committee of the Chilean Budget Office. In columns (5) and (6), we use credit rating information instead of size as criteria to define whether a firm is financially constrained or not. A firm is defined as financially constrained if it has not been rated by any of the big three credit rating agencies (Moodys's, S&P and Fitch) in 2014. In columns (7) and (8), bootstrapped standard errors (500 draws) are reported instead of clustered-by-firm robust standard errors. $CF_t$and $CF \times Small_i$ are instrumented with the spread between the spot and the forward copper prices, *spread*, and $spread \times Small_i$, respectively. Clustered-by-firm robust standard errors are reported in parenthesis: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6
Additional robustness tests (cont.).

	(1) Tsoukalas (2011)	(2)	(3) Financial crisis dummy	(4)	(5) Change in debt	(6)	(7) Additional time-varying control var.	(8)
	ΔCash	Inv.	ΔCash	Inv.	ΔCash	Inv.	ΔCash	Inv.
	Panel (a) Homogeneous effect							
CF	0.394^{***}	−0.182	0.287^{***}	−0.0749	0.408^{***}	0.0272	0.358^{***}	−0.0582
	(0.122)	(0.218)	(0.0900)	(0.206)	(0.121)	(0.144)	(0.133)	(0.144)
	Panel (b) Heterogeneous effect for small/financially constrained firms							
CF	0.147^{*}	−0.116	0.139^{**}	−0.0764	0.195^{**}	0.0239	0.155	−0.0432
	(0.0872)	(0.167)	(0.0709)	(0.174)	(0.0878)	(0.112)	(0.109)	(0.113)
CF × Small	1.179^{***}	−0.490	0.873^{***}	−0.160	0.939^{***}	−0.0951	0.874^{***}	−0.137
	(0.423)	(0.493)	(0.319)	(0.520)	(0.354)	(0.542)	(0.315)	(0.497)
Obs.	314	310	347	341	320	316	347	340
Method	IV	IV	IV	IV	IV	IV	IV	IV

Note: The table shows additional robustness tests. In particular, we re-estimate specifications (4) and (9) in Tables 2 and 3. In panel (a), the estimated cash-flow sensitivities of cash (CFSC) and investment (CFSI) coefficients (β) in specifications (4) and (9) in Table 2 are reported, and in panel (b), the estimated CFSC and CFSI coefficients (β) and its interaction with a Small/financially constrained dummy variable (β_{small}) in specifications (4) and (9) in Table 3are reported. At the top of each column, a label indicating the specific robustness check applied is shown. Following suggestions by Tsoukalas (2011) about the estimation of investment models with time-to-build, in columns (1) and (2), the ratio of lagged investment to the stock of capital is added as control variable. In columns (3) and (4) we include as additional control variable the double interaction $CF \times CrisisDummy$; where the crisis dummy (1 if year is 2008 or 2009, and 0 otherwise) controls for the potential effect of 2008 financial recession in the baseline results. In the Online Appendix we also have an equivalent specification that also includes a triple interaction $CF \times Small \times CrisisDummy$. Our coefficients of interest remain robust to these tests. The Online Appendix displays the full list of coefficients for specifications of columns (1) and (2). In columns (5) and (6), cash-flow sensitivities are estimated replacing leverage (the stock of debt) by the change in debt. In columns (7) and (8), Chinaś GDP growth rate and the IMF's Global (metal) Commodity Index are included as additional time-varying control variables. $CF_t$and$CF \times Small$ are instrumented with the spread between the spot and the forward copper prices, *spread*, and $spread \times Small$, respectively. Clustered-by-firm robust standard errors are reported in parenthesis: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

ity of cash as a deeper symptom of financial constraint in a context of time-to-build.

7. On the measurement of investment opportunities.

As outlined in the introduction, Caballero (1999) summarizes that standard Q theory performs poorly in explaining both aggregate and firm level investment. The poor performance could be due to issues such as lumpiness in investment or measurement error in Q. Regarding the latter, Erickson and Whited (2000) show that measurement error in Tobin's Q could be an artifact generating a cash-flow sensitivity when in reality there is none. As stated by Hennessy (2004), many times in investment regressions Tobin's Q is insignificant while liquidity variables like cash-flows may enter positively and significantly.

As a way to show the robustness of our results to this concern we perform additional tests using only the sub-sample of listed companies, for which we observe both indicators of investment opportunities: long run price and Tobin's Q. This allows us to compare our method with the standard one in a horse-race, *simultaneously* using both indicators of investment opportunities. Columns (6) and (7) of Table 4 show that for both the main and restricted versions of the investment regressions the long run price is positive and statistically significant, unlike Tobin's Q which is not significant. This suggests that the long run price could be a better proxy of investment opportunities than Tobin's Q. In that sense our approach could be an additional method that may be useful to bypass the mis-measurement on Tobin's Q as investment opportunities, which naturally connects our work to papers such as Erickson and Whited (2000); 2012) and Hennessy (2004).[14]

Importantly for our conclusions, even when simultaneously using both proxies for investment opportunities the CFSC remains positive and significant, while the CFSI remains small and insignificant. Therefore we are less likely to be in the scenarios described by Erickson and Whited (2000), in which the liquidity variable enters significantly in investment due to measurement error in investment opportunities. In cash-holdings regressions neither proxy of investment opportunities is significant. This is not very surprising since even the seminal paper of cash-flow sensitivity of cash does not have a robust coefficient for Tobin's Q (see Almeida et al., 2004).

Finally, in columns (8) and (9) we report a modified version of the GMM procedure by Erickson and Whited (2000), as an additional test for correcting measurement error. This is performed also using our instrument in order to consider the potential endogeneity of cash flows, which is not addressed in the original Erickson and Whited (2000) paper. In particular, our modified Erickson and Whited (2000) procedure consists in using fitted cash flows instead of cash flows in the GMM estimation procedure proposed to deal with measurement error. The fitted cash flows are obtained from a regression of cash flows on our instrument, the price spread, and additional control variables. Results show that the CFSC is positive and significant for the full sample. However, the effect disappears when we look at the differential effect on small firms. The long-term copper price, which is the variable affected by the correction proposed by Erickson and Whited (2000), now becomes positive and significant in the change of cash holding regression but still not significant in the investment regression. The bottom line is that the CFSC remains significant, although some specifications do not show an extra effect among financially constrained firms.

Overall the different tests suggest that our results regarding the primacy of CFSC in this context of time-to-build is not an artifact of measurement error.

As mentioned, relying on an indicator of long run fundamentals could be appealing both due to the obvious connection to the industry's investment decisions as well as for its empirical relevance described above. We view this method as a useful proxy for future studies in contexts of time to build. Although, it is still important to acknowledge the potential limitations of this approach of proxying for the investment opportunity set. A first clarification is that our approach does not consider the particularities of each mine, including the concentration of copper in the mines' ores, because the long run price is a single index for the whole world. Secondly, the long run expectations regarding the commodity price do not actually represent the set of investment possibilities. Its change is simply a *shifter* to the set of investment possibilities. In that sense it is different from Tobin's Q which could have a direct interpretation as a set of investment possibilities when Q is above one. Having said that, most theoretical models rely on marginal Q, while empirical models use some version of average Q. One could think that our long run price shifter could be a better proxy for changes in marginal Q. However, there might be heterogeneity because different mines may have different cutoff long run prices for reacting with additional investment, and we do not observe that. Thirdly, future market prices or the experts' predictions may still inaccurately measure the true unobservable expectations. In our estimations we are controlling for many aspects as a way to minimize this concern; for example including as controls the interest rate and Chinese growth, as well as a price-index of other metals that may be related to market conditions but that should not be directly affecting the profitability of copper companies. In addition, we used two different proxies for long run expectations. Overall our method is an added option in the toolbox, but we are not claiming it necessarily dominates all the others.

8. Different samples and additional robustness

8.1. Heterogeneity between listed and unlisted firms

Another potential concern is that our full sample mixes both listed and unlisted firms, so our results might be driven solely by one group. In order to deal with this issue, we estimate an extended version of Eq. (1) in which both a publicly listed variable dummy ($dListed_i$) and its interaction with cash flows are introduced ($CF_{it} \times dListed_i$). We also have regressions adding the additional term $CF_{it} \times dListed_i \times Small_{it}$ when looking at financially constrained firms, which correspond to extensions of Eq (2).

For both estimated specifications, our results are qualitatively similar to our baseline in Section 5. The basic CFSC is positive and significant, especially for financially constrained firms, while the corresponding results on CFSI are statistically insignificant. For some specifications (detailed in the Online Appendix) there are positive interactions with $dListed_i$, meaning a higher CFSC among listed firms. Nonetheless this additional effect on listed firms is not significantly stronger for small or financially constrained companies, suggesting that it could be proxying for some other channel.

Finally, in previous tests we also analyzed both samples *separately*, obtaining again a positive CFSC and an insignificant CFSI.[15]

8.2. Additional robustness

In this last section of robustness checks we explore additional concerns that could potentially impact the validity or interpretation of our estimates.

8.2.1. Alternative long run price expectations, measure of financial constraint and standard errors.

There may be potential concern that a three year horizon would be too short to entail a long term expectation regarding copper prices. To address this concern we repeat our previous analysis replacing the forward copper price with the long-run price estimated by a Committee of Experts from the Chilean Ministry of Finance (see Section 4).[16] Results in columns (3) and (4) of Table 5 are qualitatively similar to our main specifications, with the CFSC being positive and stronger among financially constrained firms. At the same time, specification (4) confirms that the estimates of CFSI are statistically indistinguishable from zero. So using a different proxy for long run prices did not change our central story.

We also try different proxies for financial constraints.[17] As an additional measure we include a more direct indicator of financial

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[14] In the Online Appendix we also have tests that instead of having both variables for investment opportunities, include just one of them at the time. In that case our CFSC is almost unaffected by the change in proxy for investment opportunities. Moreover, in both cases the CFSI was statistically insignificant, suggesting that possibly the measurement error in Q was not the cause of cash-flow sensitivities to appear positive.

[15] See columns (6) and (7) in Table 4 for listed firms; with further tests in the Online Appendix for different specifications. For a discussion of why Joint Ventures and other structures may have segmented cash management with respect to the main corporation see our Online Appendix. Joint Ventures are the majority (67%) of firms in our sample of unlisted firms.

[16] The aim of this Committee is to provide an estimate of the copper price in the next 10 years to be used in the structural budget policy. The committee has been consulted annually since 2002, formed by around 10 experts and following a similar method since then. The data is available at http://www.dipres.gob.cl/594/w3-propertyvalue-16158.html

[17] The basic results on Section 5 use a dummy for smaller companies as the sorting criteria to proxy for financial constraints. In previous versions of the paper we also used the dividend payout policy as an alternative criteria. Various papers such as Hadlock and Pierce (2010), Farre-Mensa and Ljungqvist (2013) and

Table 7
Reduced form regressions.

	(1) Δ Cash	(2) Inv.	(3) Δ Cash	(4) Inv.
Spread	0.122***	0.00535	0.0526*	0.00959
	(0.0387)	(0.0561)	(0.0277)	(0.0417)
Spread × Small			0.253***	−0.0454
			(0.0824)	(0.154)
Small			0.0128	−0.145
			(0.0865)	(0.119)
LT Copper Price	0.149**	0.225**	0.145**	0.224**
	(0.0754)	(0.0921)	(0.0719)	(0.0910)
Size	−0.230***	−0.354**	−0.215***	−0.376**
	(0.0857)	(0.155)	(0.0721)	(0.158)
Leverage	−0.0868	−0.443**	−0.116	−0.412***
	(0.0954)	(0.173)	(0.102)	(0.156)
Interest rate	−0.0247**	−0.0170	−0.0227**	−0.0161
	(0.0117)	(0.0154)	(0.0109)	(0.0146)
Obs.	347	341	346	340
R^2	0.216	0.309	0.258	0.322
Firm-FE	Yes	Yes	Yes	Yes
Method	OLS-FE	OLS-FE	OLS-FE	OLS-FE

Note: In columns (1) and (2), panel estimates of the reduced form model $y_{it} = \delta spread_t + \gamma_1 LTCopperPrice_{t-1} + \gamma_2 X_{it-1} + \mu_i + \varepsilon_{it}$ are shown, and in columns (3) and (4), panel estimates of the reduced form model with interactions for small firms, namely $y_{it} = \delta spread_t + \delta_{small} spread \times Small_i + \gamma_1 LTCopperPrice_{t-1} + \gamma_2 X_{it-1} + \mu_i + \varepsilon_{it}$. Variable y_{it} is either $\Delta Cash\,Holdings_t$ or $investment_t$, while $spread_t$ is the spread between the spot and the 27-month forward copper prices in *t*, *small* is a dummy variable that takes the value of 1 if the firm belongs to the three lower deciles according to the firm's size, *LTCopperPrice* is 27-month forward copper price, *Size* is the demeaned natural logarithm of total assets, *Leverage* is the ratio of total debt to lagged total assets, *InterestRate* is the 3-year US Treasury constant maturity rate. Clustered-by-firm robust standard errors in parenthesis: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

constraint, namely the credit rating. Firms with better credit rating would in principle have an easier time raising funds for future investments, so there is less need to stockpile cash today. We use the most frequent indicator of constraint in this literature: a dummy variable with the absence of credit rating. Columns (5) and (6) in Table 5 display the results showing again a positive CFSC, especially among constrained firms; while the CFSI remains statistically insignificant. Therefore our results are robust to this measurement concern for financial constraint.

Finally, to address potential concerns with our clustered standard errors and more specifically with potential small sample biases, columns (7) and (8) of Table 5 show results with bootstrapped standard errors. Again, this does not change our central result of a robust and significant CFSC, stronger and more precise than the CFSI.

8.2.2. Potential measurement error in time to build and the great recession

As discussed, time-to-build is a central attribute for our study. According to Tsoukalas (2011) time-to-build could also yield to some measurement error since savings today may be a function of previously made investment decisions. To check that our results are robust to this concern we follow Tsoukalas (2011)'s suggestion and include the ratio of lagged investment to the stock of capital as an additional control.[18] Table 6 shows in columns (1) and (2) that results that are fairly similar to our main regressions in Section 5. In short, we take this as evidence that our central results seem robust to concerns about measurement error in this context of time-to-build. Another concern is that our estimates might be capturing the effect of the 2008–2009 financial crisis and recession. In fact the price of copper dropped by approximately 60% during the crisis period. We address this potential concern by first incorporating a dummy variable that takes the value of one during 2008 and 2009, and zero otherwise. One can also be concerned that our IV estimate of β could be biased due to the Great Recession, therefore, we also included an interaction between cash flows and crisis. The main coefficients of interest β and β_{small} are qualitatively unchanged when we performed this exercise in columns (3) and (4) of Table 6.

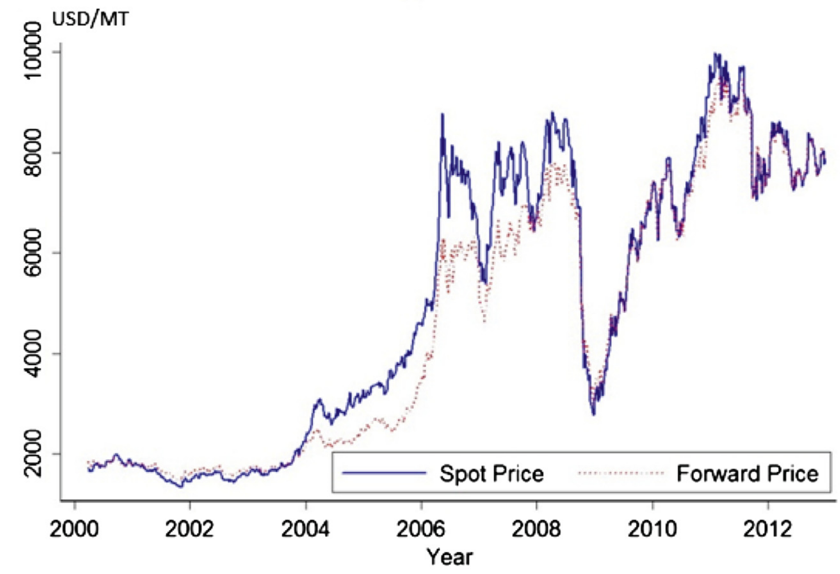
8.2.3. Alternative control variables and lags

In our main specification we add leverage to control for the importance of borrowing vis-à-vis cash savings. However, leverage is a stock variable and its fluctuations may be a function of changes in assets rather than debt. As a robustness check we approach the regressions by Almeida et al. (2004) and Almeida and Campello (2007) and include change in debt to control for debt financing behavior. This could increase endogeneity of the estimates, therefore the robustness check is taken with some caution. In any case, the results in columns (5) and (6) of Table 6 do not qualitatively change our central findings. Another potential concern with our basic specification is that any time-varying effect is only captured by the long-run copper price and, in some specifications, the interest rate. If another important time-varying variable is omitted, our results may be biased. To mitigate this concern we include two additional control variables: China's GDP growth rate and a global commodity price index, both from the IMF. In particular, we use the commodity metal price index as our global commodity index to explore whether our results are driven by something that is not just copper prices but instead a trend common to all commodities or possibly a proxy of global activity. Columns (7) and (8)

Figueroa and Wagner (2014) argue that size and age are useful predictors of financial constraints. While we included size from the very beginning, we are hesitant to include age because of the time-to-build. Very new firms are unlikely to have sales since it takes many years to start producing. Also, since we are dealing with both publicly and non publicly traded companies it is less obvious how to find a common method for measuring age. The well known shortcut of using the years since the first appearance in COMPUSTAT is not available as a strategy for the fraction of our sample whose shares are not public. For these reason we stayed with alternative measures like the absence of credit rating.

[18] Tsoukalas (2011) also suggests including as a control the growth rate of the stock of capital to manage time-to build. We do not include this variable as a control in our specifications because it is highly collinear with our definition of investment. One has to acknowledge that our approach of instrumented cash flows is different from Tsoukalas (2011) that lacks an instrument, so we might be less worried about the concern of measurement error on contemporary investment. In any case, later in the robustness checks section we run tests of how cash flows matter for investment in the future.

(a) Spot and 27-month Forward Copper Prices



(b) Spread between Spot and Forward Copper Prices

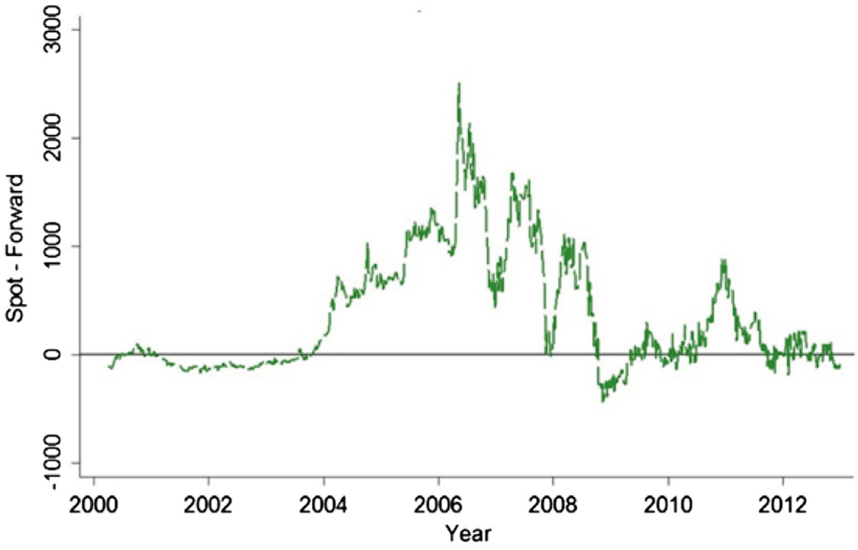


Fig. 3. Copper prices 2000–2013: spot, forward and spread Panel (a) displays the spot and forward copper price (27 months); while panel (b) displays the spread or difference between these two series above. Prices in USD per metric ton which is equivalent to 0.45 USD per pound of copper. For further details see the explanation for each series in Section 4.

in Table 6 report our results showing that estimates are not particularly affected by the inclusion of these additional time-varying control variables. Our effect seems to be related to copper prices rather than some other obvious time-varying variables.

In our Online Appendix we show additional results in which current instrumented cash-flow tends to impact investment in financially constrained firms approximately two to three years in the future. Despite estimation challenges, this is also suggestive evidence consistent with time-to-build.

9. Concluding remarks

This paper explores financial constraints in projects that take time to build or are slow to yield cash flows. In particular the paper focuses on how mining corporations have saved surprising cash windfalls during the recent commodity boom, using a global sample of firms between 2002 and 2012. We exploited the fact that the copper mining industry offers a peculiar advantage: given the time-to-build in these operations, investment decisions depend on the expectations of the long run price of copper, while current cash flows depend on the spot commodity's price, having meaningful variation that can be exploited for identification.

Our results show systematic cash flow sensitivity of cash holdings, meaning that some of these transitory earnings are stockpiled as liquidity, at least in the short run. This cash stockpiling out of cash-flows is systematically stronger among the most financially constrained firms. In contrast, we do not find much evidence supporting a simultaneous cash-flow sensitivity of investment. Our findings on liquidity support financial theories remarking the salience of cash as buffer stock for liquidity of financially constrained firms (Almeida et al., 2004).

In addition, in this paper we show a clear case in which the cash flow sensitivity of cash and that of investment are unlikely to be substitutes as measures of financial constraints. When firms face time-to-build, then financial constraints may appear in cash holdings rather than in investment.

Our instrumenting strategy based on the differential of current and future expected revenues could be of independent interest to researchers in other industries with time-to-build, including bulk transport (e.g. Kalouptsidi, 2014).

Although we identify cash stockpiling due to our instrument, we acknowledge that our work still has relevant limitations to help understand broader measures of liquidity. In fact, a more recent literature (e.g. Sufi, 2009; Almeida et al., 2013) recognizes that firms use many types of *contingent* liquidity lines that do not appear in standard accounting aggregates, such as credit lines with banks or suppliers. While this remains a challenge for future research, we adhere to the view of Campello (2015), in which cash remains "king" because it is a non-contingent liquidity, available in all states of nature.

Appendix

A1. Reduced form estimates for main specifications

To complement our instrumental variable regressions Fig. 1 in Section 4 already showed that cash stockpiling accelerated when the spread was larger. Here Table 7 displays the reduced form estimates of panel regressions of our baseline results. Columns (1) and (2) are similar to the baseline IV regressions of Eq (1) in Section 5, but using only the second stage and replacing the endogenous cash-flow by the exogenous spread in prices. As expected, the coefficients are statistically significant and have a positive sign for changes in cash holdings, while the effect on investment is statistically zero. Of course the magnitudes are different from our IV estimates in Section 5, because the reduced form coefficient is not scaled by first-stage. Columns (3) and (4) display the reduced form for the interacted model equivalent to Eq (2). The results confirm that interaction between the $spread_t$ the dummy $small_i$ is statistically significant and has the expected sign, which is consistent with the IV estimates and also with Fig. 1. Summing up, the reduced form estimation is consistent with our main results in the paper.

A2. Copper prices over our sample period.

Fig. 3 displays the evolution of the spot price and the forward contract for copper in Panel (a), while Panel (b) described the spread or difference between the previously mentioned time series of copper prices.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.compfluid.2016.09.001

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