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“Flexibility and Firm Value: The Role of Inventories”

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Flexibility and Firm Value: The Role of Inventories

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Abstract

In the present thesis I study the contribution to firm value of inventories management from a risk management perspective. I find a significant contribution of inventories to the value of risk management especially through the operating flexibility channel. In contrast, I do not find evidence supporting the view of inventories a reserve of liquidity. Inventories substitute, albeit not perfectly, derivatives or cash holdings. The substitution between hedging with derivatives and inventory is moderated by the correlation between cash flow and the underlying asset in the derivative contract. Hedge ratios increase with the effectiveness of derivatives. The decision to hedge with cash holdings or inventories is strongly influenced by the degree of complementarity between production factors and by cash flow volatility. In addition, I provide a risk management based explanation of the secular substitution between inventories and cash holdings documented, among others, in Bates, Kahle, and Stulz (2009). In a sample of U.S. firms between 1980 and 2006, I empirically confirm the negative relation between inventories and cash and provide evidence on the poor performance of investment cash flow sensitivities as a measure of financial constraints also in the case of inventories investment. This result can be explained by firms' scarce reliance on inventories as a reserve of liquidity. Finally, as an extension of my study, I contrast with empirical data the theoretical predictions of a model on the integrated management of inventories, trade credit and cash holdings.

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Introduction

In this thesis I study the contribution of inventories to firm value through the risk management channel.[1] Although operating motivations are important, I focus on financial factors that provide complementary motivations for holding inventories. More specifically, I concentrate on the study of inventories from a risk management perspective on top of other theories related to operating processes. The area of risk management that I target is the hedging of cash flow.[2] [3] The volatility of cash flow may cause significant costs for the firm like distress costs, bankruptcy costs, increases of tax payments as emphasized by Smith and Stulz (1985), external finance costs and underinvestment as in Froot, Scharfstein, and Stein (1993), loss of tax shield as in Leland (1998). Under the perspective of firm's value maximization, the probability of incurring these downside costs requires attention from firm's managers who need to implement suitable risk management strategies. Along with traditional risk management strategies, the dynamic management of inventories constitutes a valuable alternative.

With the present work, I contribute to existing literature in a number of ways. First, I give guidance on the magnitude of the contribution of inventories management to firm value through the channel of risk management, isolating it from operating considerations. Specifically, I assess how inventories management adds value through operating flexibility and through its role as a reserve of liquidity and under which circumstances. Second, I compare inventories management contribution to risk management in the presence of other traditional risk management tools like derivatives and cash holdings. The objectives of this comparison are to gauge the contribution to value of each risk management tool, to understand whether these hedging strategies are substitutes or complements, to provide guidance in the integrated management of these three

[1] I consider total inventory taken as the total sum of raw materials, work-in-process products and finished products. According to Ramey (1989) I classify raw materials and work-in-process products as input inventory and finished products as output inventory.

[2] Traditionally, in the finance literature cash flow, or operating cash flow, or internally generated funds, refer to cash flow from operations. Free cash flow is given by internally generated funds less investment expenditures. External finance is given by funds obtained from financial markets.

[3] In contrast to cash flow hedging, value hedging refers to implementation of strategies aimed at preserving the value of an asset or liability. For example, entering a derivative contract to swap a fixed with a floating interest expense protects the value of debt but leaves firm's cash flow exposed to fluctuation in interest rates.

hedging tools. Of particular importance is the relation between inventories and cash holding in light of recent studies, like Bates, Kahle, and Stulz (2009), documenting a secular substitution between these two working capital assets between the 1980's and 2000's. Third, in relation to the role of inventories a reserve of liquidity, I provide theoretical and empirical evidence on the weakness of investment cash flow sensitivities as a measure of financial constraints also for inventories investment. Fourth, I investigate the relations between inventories, cash holdings and trade credit under an operating and risk management perspective.

I organize my research in two stages. In the first part, I concentrate on the construction of a theoretical model on inventories. In the second part, I empirically test the main predictions of my model. The area of study of *dynamic corporate finance* is the natural theoretical environment in which I place my model.[4] The investment in inventories along with other firm's policies involves an important dynamic dimension. In dynamic models on investment three or more periods of time are required to fully analyze the causes and the effects related to real investment policies that static models fail to capture. For example, assuming a three-periods discrete-time environment, managers need to take into consideration the effects of investment decisions at the time of the decision, time 0, and the subsequent periods, time 1 and time 2. At time 0, the investment derives from the optimal allocation of firm's resources several uses taking into account budget constraint concerns. The optimality of an investment plan requires the balance of cost of the investment at time zero with its expected return at time 1 and possible future investment opportunities that realize at time 2. Also hedging and saving decisions require a dynamic framework. For example, hedging with derivatives requires some down-payment, like margin requirements, at contract inception and for this reason it vies with other possible uses of funds, as emphasized in Rampini and Viswanathan (2010). At time 1, the derivative pays off. The decision to hedge at time 0 is deeply influenced by the use of funds generated by the derivative at time 1, then also for hedging decision it is important to consider the expected return, realized at time 2, of the funds allocated at time 1. As for savings, at time 0 the firm subtracts funds to investments and hedging to preserve resources that will be used at time 1. Also in this case, the use of saved funds at time 1 influences the decision at time 0 to hold cash against distributing it to shareholders.

The study is organized in three Chapters. In Chapter 1, I review the areas of study relevant to my research. First of all, I report the main theoretical and empirical contributions on inventories management in the economic literature. Secondly, I review the risk management contributions that constitute the theoretical foundations of my work. Also empirical studies

[4]See Strebulaev and Whited (2012) for a review.

on risk management are reported for comparison with predictions of theories. Thirdly, I study the part of the literature on cash holdings most closely related to risk management. Finally, I review also the main theories that explain the existence of trade credit as a background of Chapter 3.

In Chapter 2, I study the channels through which the management of inventories contributes to firm value in isolation and in presence of other risk management tools. Inventories contribute to firm value first of all as a production factor. After controlling for their role in operations, inventories constitutes a valuable risk management tool for two main reasons. First, according to Ramey (1989), inventories provide operating flexibility in the form of avoidance of uncertainties related to the production and sales processes. Operating flexibility increases operating cash flow thereby mitigating financial constraints. Second, according to Fazzari and Petersen (1993), inventories are a liquid assets and can be used as a reserve of liquidity in the event of negative shocks to cash flow. In the prosecution of this work, we will see if these two sources of value related to inventories are important and in which circumstances. In addition, I comparatively assess the risk management contribution of inventories management by comparing it with hedging and cash holdings. In the first part of Chapter 2, I construct and solve a theoretical model on the integrated management of inventories with hedging or cash holdings. The model is used to evaluate the risk management contribution of inventories and to analyze the correlation between firm's policies. One of the main predictions of the model is the negative relation between inventories and cash holdings. I empirically test this prediction with particular attention also to the impact of financial constraints on inventories investment. The sensitivity of inventories investment to financial constraints reveals insights on the role of inventories as a reserve of liquidity.

In Chapter 3, I extend the model developed in Chapter 2 to study the integrated management of working capital items like cash, accounts payable and inventories. Trade credit is seen as a flexible source of financing especially for financially constrained firms. However, collateral requirements on inventories stock and enforcement of contracts attenuate the benefits of trade credit. Secondly, I investigate the relation between trade credit and cash holdings.

Chapter 1

Literature Review

1.1 Inventories in the Economic Literature

Abramovitz (1950) argues that before the second World War inventories fluctuations accounted for the most part of output recessions in the U.S. Blinder and Maccini (1991) report that in the U.S. postwar recession inventories divestment accounted for the 87% for the GNP fall. Blinder and Holtz-Eakin (1986) enlarge this measure to roughly the %100. Moreover, Blinder and Maccini (1991) add that the reduction of inventories' stock accounted for most part of the GNP contraction during the 70's crisis. Ramey (1989) report that during the 1981-1982 when the U.S. real GNP fell by \$105 billions, inventories, that averaged only a 0.7% of GNP, declined by \$95 billions accounting for 90% of GNP contraction, while fixed assets fell by \$58 billions, say, a 55% of GNP decline. Ramey and West (1999) report a very small aggregate inventories investment across G7 countries at that time for the period 1956-1995. For example, inventory investment averaged at most 1% of GDP in Italy and lower in other countries. Ramey and West (1999), confirm previous findings also related to the relatively high volatility and procycclicality of inventories investment.

Another stylized fact is the secular decline in inventories holdings in many developed countries from the end of the 1970's to the 2000's. The decreasing trend of inventories has been documented in Hester (1994) and Ramey and West (1999) for the U.S. and by West (1992) also for Japan. At the firm-level Bates, Kahle, and Stulz (2009) emphasizes the substitution trend between inventories and cash in the U.S. between 1980 and 2006. Larson (1991) attribute the decline of inventories levels during the 1980's to the increasing interest in just-in-time (JIT) production by American firms. He adds that it would have been hard to observe a growing rate of firms implementing JIT without deregulation of transportation, begun in 1980 in the U.S., that hugely reduced shipping costs. White, Pearson, and Wilson (1999), using a survey-based sample of U.S. manufacturers, find that JIT adoption is pervasive among large firms while small firms, which are the 96% of the U.S economy, struggle to implement it. The motivations for this difference relate to the lack of influence over suppliers, production schedule instability and the lack financial resources to be invested in the implementation of JIT, that requires training and organization improvements that are expensive. White, Pearson, and Wilson (1999) also find that JIT system is more likely to produce performance benefits for large firms than for their smaller counterparts. Chen, Frank, and Wu (2005) study the secular decrease in inventories holdings between 1980 and 2000 in a sample of U.S. manufacturing firms. They provide evidence on the decrease of the cross-sectional average of the use of inventories measured with inventories to asset ratio, inventories to sales ratio and days in inventories. While the use of raw materials and work-in-process substantially decreased over time, the use of output inventories increased. More specifically, the authors suggest that supply chain and technological improvements, like the adoption of just-in-time production or the reduction of transportation costs, are responsible for the decrease of input inventories holdings and particularly for work in process. Chen, Frank, and Wu (2005) provide also evidence on the relationship between days in inventories and firm's financial performance measured with stock returns. They employ traditional asset pricing methods, like the popular Fama and French (1993) method, to test if inventories holdings have impact on firm value. They find that firms with very large or very small stock of inventories perform worse than firms between the second and fourth deciles of the distribution of portfolios of stocks sorted on a measure of abnormal inventory days robust to industry fixed effects. The authors conclude that even though technology factors, like the just-in-time system of production, probably affected the firm's inventories policy, it also true that firms prefer to hold less inventories in a quantity that allows them to manage supply chain risks and demand risks that just-in-time production, or reliance on multiple suppliers, cannot eliminate.

Empirical evidence has stimulated the interest in inventories research aimed to explain the economic motives behind inventories holdings. The theoretical research on inventories basically started with the contribution of Holt, Modigliani, Muth, and Simon (1960) who developed the foundations of the so-called *production smoothing* motive for holding inventories mainly in the fields of microeconomics and operations management. In this theory, inventories serve only to smooth the marginal revenue of production across time when product sales change over time. The basic assumption is the existence of convex marginal cost of production and production adjustment costs that make very costly to adjust production in response to demand variation. Having output inventories allows the firm to leave production decisions unchanged and to satisfy demand. Abel (1985) provide support to the production smoothing motive by removing the convex production costs assumption and relying on a time lag between production and sales and on the possibility of stock-out which is a cost for the firm. Another feature of the production smoothing theory is the positive relation between product demand volatility and inventories investment. If product demand is stochastic firms may decide to hold inventories as buffer against demand fluctuations in such a way that some quantity of inventories will be held also by firms' managers not willing to pursue an aggressive inventories policy.

The production smoothing theory, although very intuitive and reasonable, is at odds with patterns in empirical data on inventories behavior at cross-sectional and time series level, according to Blinder (1986a) and West (1986). The first flaw of the production smoothing theory regards the variability of production predicted lower than the variability of sales even after controlling for seasonal factors that strongly influence inventories behavior as in underscored in Blanchard (1983). This is in sharp contrast with data showing exactly the opposite pattern with production volatility exceeding sales volatility. Secondly, according to the production smoothing theory firms invest in inventories when production costs are low which typically happens in periods of output expansion. However, according to Ramey and West (1999) who study macroeconomic data of the G7 countries from the postwar period to 1995, inventories investment is strongly procyclical, in agreement with Rotemberg and Saloner (1989), very volatile and not very persistent. Only the ratio of inventories to sales is negatively correlated with output and quite persistent. These statistical characteristics of inventory behavior hold both within the U.S. and across the most developed countries studied in Ramey and West (1999).

In order to fix the defects of the production smoothing framework various theoretical contributions have been tried. The first answer was given by the contributions of Blinder (1986a) and Eichenbaum (1984) where production cost shocks were added to the production smoothing model in order to obtain production more volatile than sales. However, this approach has been posed under question because of the lack of evidence on production cost shocks. Another more promising theory was the one developed by Kahn (1987, 1992) and Bils and Kahn (2000) which focuses on the *stock-out avoidance* motive for holding inventories, earlier introduced by Abel (1985), and assumes a time lag between production and sales, that obliges firms to make decisions before demand is known, and sales persistence. More specifically, Kahn (1987) shows that firms invest in inventories taking into account the possibility of stocking out and consequently loosing demand. On the other side, if demand realizes lower than expected, inventories are carried forward with cost. The basic implication of Kahn's model is that loosing sales is on average more costly than inventories carrying costs so that firms are stimulated to hold inventories. The second implication of Kahn's theory is that if demand is persistent firms will try to catch it by increasing production and thereby inventories. On the contrary, if firms expect a low demand they will cut inventories. This proposition is in agreement with empirical evidence where inventories investment is positively correlated with sales in contrast with the production smoothing theory that proposes a negative correlation. To this regard, Kahn (1987) writes of inventories used to "counter"-smooth production rather than smooth it. Another prediction of Kahn's model is the higher volatility of production compared to sales volatility, in agreement with previous empirical findings.

Bils and Kahn (2000), adding to the contribution of Kahn (1987), argue that firms do not adjust inventories according to some target, as it is proposed in studies like Holt, Modigliani, Muth, and Simon (1960) and Blanchard (1983) that adopts the linear-quadratic model in a production smoothing framework. In contrast, firms follow the direction of product demand. This theoretical proposition is in full agreement with the findings in Feldstein and Auerbach (1976) who report that firms adjust inventories stock very slowly, compared to the speed implied in models of production smoothing with target levels, after even very small changes in sales targets. Then, it is reasonable to argue that the benefit of avoiding stock-outs creates a demand for inventories besides any production-smoothing motive. The adjustment toward inventories target levels is of secondary importance.

The framework of Kahn (1987) is coherent with the contribution of Ramey (1989) where inventories are fully recognized as production factor providing a flow of services in the same manner as fixed assets. To be fair, Kydland and Prescott (1982) previously introduced inventories into a traditional neoclassical production function. However, this modeling approach was introduced by Kydland and Prescott only to obtain a better fit of their model with empirical data. One of the services provided by input inventories is the possibility to cope with supply chain shocks that limit the quantity or the quality of input supplied. Output inventories help to satisfy demand when production is stopped because of technology shocks like machines malfunctioning. The services provided by inventories comprise also the avoidance of production adjustment costs in the same spirit as the production smoothing models. However, in Ramey (1989) avoiding production adjustment costs is already included in the revenue from inventories investment in the form of marginal productivity. Finally, Ramey (1989) considers also avoidance of stock-outs as an additional benefit from holding inventories. Here, and according also to Bils and Kahn (2000), the difference with the production smoothing theory is that firms adjust inventories mainly according to their expectations of future demand. Since demand is stochastic, expectations will change and also sales target will change accordingly. If demand is expected low also the benefit of satisfying demand deviations from target sales will be small and viceversa. Ramey (1989) emphasizes also the role of input inventories which on average constitutes the largest share of total inventories and are by far more volatile than output inventories, as observed in Blinder and Maccini (1991).

The approach of Ramey (1989) is taken also in real business cycle studies like Kydland and Prescott (1982) and Christiano (1988) where inventories are considered a factor of production included inside a neoclassical production function. The revenue from inventories in these neoclassical models is given by marginal productivity which corresponds to the benefits provided by inventories listed by Ramey (1989). In addition, the adoption in Kydland and Prescott (1982) and Christiano (1988) of a Constant Elasticity of Substitution (CES) production function allows to appreciate the important flexibility value embedded in inventories given by the substitutability with other production factors. For example, Ramey (1989) points out that firms use inventories to satisfy demand when production is switched off for any reason. Instead of producing, using capital and labor, inventories can be used to collect products to be sold. More generally, the degree of substitutability of inventories with other production factors importantly determines inventories return.

The commodities literature focused on the value of storage,[1] intersects with the macroeconomic literature on inventories thanks to the work of Pindyck (1994). The services provided by inventories listed by Ramey (1989) and embedded inside the inventories marginal revenue in neoclassical models, correspond to the *convenience* of holding inventories in Pindyck (1994). Such a convenience is modeled by means of a cost function convex in inventories stock which is equivalent to the concave revenue of inventories in the model of Kydland and Prescott (1982). Besides the different modeling approach, Pindyck (1994) provide arguments similar to those in Kahn (1987) and Ramey (1989) like, for example, the possibility to avoid stock-out costs because of inventories. The avoidance of stock-outs, obtained by raising the level of inventories stored, translates into a lower cost given the convex shape of the cost function adopted. Pindyck (1994) empirically extends his theoretical study of inventories investment to a sample of U.S. producers of heating oil, copper and lumber, observed between 1972 and 1988, and finds a strong convenience of holding inventories declining with the level of inventories itself.

Another part of the inventories literature concentrates on fixed costs of obtaining inventories incurred in each stage of the business. These costs are represented by input orderings, production set-up and shipping costs as in Scarf (1960) and Fisher and Hornstein (2000). According to

[1]See Kaldor (1939), Working (1948, 1949), Brennan (1958) Telser (1958).

these studies, firms hold inventories for example because it is costly to order production input so that orders with optimal size are placed only when inventories stock falls below a certain threshold level. The resulting inventory investment policy is called (s, S) where the s is the threshold and S the size of the order. A merit of these studies is the focus on input inventories which are significant component of total inventories.

Besides operating motives for holding inventories, a strand of literature has rather focused on financial motives that may explain inventory behavior. In early literature on inventories little or no attention at all was devoted to the relation between the real interest rate and inventories. Later, it was proposed that financial markets frictions play a role in the propagation of business cycle shocks, including monetary policy shocks, because of information asymmetries between borrowers and lenders.[2] The literature on the transmission of the monetary policy detects, within the credit channel of policy transmission, basically two subchannels through which financial frictions affect real investments according the emphasis posed on credit supply or NPV considerations. The effect of the financial market frictions on credit, and consequently on investments, can be detected through a net worth (or balance sheet) channel and a bank lending channel. According to the former channel, a shock to firm's cash flow and assets value, like a restrictive monetary policy, determines a contraction of the firm's net worth pledgeable for financing. According to the latter channel, tight monetary policies reduce the amount of funds available thereby reducing the possibility for banks to grant credit. The outcome of a shock, which follows either of the two channels, is a reduction of external finance that leads to a contraction of firm's investments. Information asymmetries not only moderate the transmission of monetary policies but may also lead lenders to ration credit, as explained by Stiglitz and Weiss (1981), and push firms to prefer internally generated funds instead of issuing costly new equity, as highlighted by Myers and Majluf (1984).

On the basis of theoretical propositions on the relation between financial constraints and real investment, a series of empirical studies have been proposed especially for fixed capital investment but also for working capital investment. The main proposition to be tested is that, if capital markets are imperfect, firms with scarce internal funds will invest less and find optimal to reduce investments or even cut some of their assets to raise liquidity. The response to internal cash flow shock will be different from asset to asset according to the relative degree of reversibility and liquidity. Since inventories are typically more easily reversible and liquid than fixed assets they are more likely to be reduced after negative shocks to cash flow. In summary, costly external finance raises up the cost of capital thereby discouraging

[2] See Gertler (1988), Bernanke and Gertler (1989) and Bernanke and Gertler (1995).

investment to the point that firms may even decide to cut assets starting from liquid assets. Fazzari and Petersen (1993) provide evidence on the high sensitivity of working capital asset to shocks to cash flows in an indirect manner. Using a sample of U.S. manufacturing firms for the period 1970-1979, they show that it is possible to effectively overcome issues related to possible mismeasurement of Tobin's Q, a noisy proxy for investment revenues, by controlling for investment in working capital in fixed capital investment regressions. They find a positive and significant sensitivity of fixed capital investment to cash flow after controlling for working capital that proxies for fluctuations related to expected marginal revenue of investment. In this way, they obtain a investment sensitivity to cash flow that only measures the effects of budget constraints, intuitively because, in the presence of fixed capital investment convex adjustment costs, working capital variations according to cash flow help to smooth fixed capital investment across time. Gertler and Gilchrist (1994) examine the response of small compared to large firms to tight monetary policies. Size is taken as a proxy for the access of a firm to capital markets because constrained firms are typically small, young and risky firms with low collateral, in agreement with Fazzari, Hubbard, and Petersen (1988). Using a sample from *Quarterly Financial Report of Manufacturing Corporations* for the period 1958-1991, Gertler and Gilchrist (1994) report that, in response to a restrictive monetary shock, small firms reduce, among other variables, inventories more severely than large firms. In addition, such a behavior is more pronounced during macroeconomic downturns indicting that the flexibility to reverse inventories investment is particularly valuable in periods of low profits. Also important is the finding in Gertler and Gilchrist (1994) of strong predictive power of the coverage ratio with respect to inventories investment in agreement with arguments in Fazzari, Hubbard, and Petersen (1988). Kashyap, Lamont, and Stein (1994) investigate the effect of financial factors on inventories investment in sample of U.S. manufacturing firms from COMPUSTAT database around the 1981-1982 recession, typically considered as a monetary induced recession. They find not only that financial factors, like liquidity measured by the cash ratio, have an impact on inventories investment but also that firms more dependent on bank credit and with no access to market debt decrease the stock of inventories much more sharply than firms with easier access to capital markets. Carpenter, Fazzari, and Petersen (1994) and Carpenter, Fazzari, and Petersen (1998) provide empirical evidence on the positive relation between firm internal cash flow and inventory investment in a sample of U.S. firms drawn from COMPUSTAT for the 1981-1992 period. Their basic hypothesis follows the arguments of Fazzari and Petersen (1993).

Turning the attention to the relation between interest rates and inventories investment, the model in Ramey (1989) implies a negative relation between interest rate and inventories investment through the rental rates of inventories. Price speculation would suggest that when interest rates are expected to increase, so that prices are expected to decrease, firm will hold less inventories. However, Blinder and Maccini (1991) report that no significant effect of real interest rate on inventories investment is found in the empirical literature on inventories. In addition, Kashyap, Lamont, and Stein (1994) suggest that the lending channel can explain, better than the cost of financing (balance sheet) channel, the relation between shocks to monetary policy and inventory investment. Moreover, they add that credit rationing may limit the possibility to detect any relation between interest rates and inventories. In sharp contrast, recent contributions, like Maccini, Moore, and Schaller (2004) and Jones and Tuzel (2013), provide different conclusions. Maccini, Moore, and Schaller (2004) provide evidence of a long-run cointegration relation between real interest rate and inventories in the aggregate U.S. manufacturing between 1959 and 1999. They argue that previous studies failed to find any relation between interest rates and inventories investment because they were focused on the short-term variations of interest rates. Conversely, in the long-run the real interest rate is significantly and negatively correlated with inventories investment. Then, according to Maccini, Moore, and Schaller (2004) firms adjust inventories only in response to shift in the long-term mean of the real interest rate.

Jones and Tuzel (2013) argue that the reason why previous studies do not find any significant relationship between interest rates and inventories investment is that the real interest rate is not the correct measure of the cost of capital. The proposition of Jones and Tuzel (2013) confirms the findings in Thomas and Zhang (2002) where most part of the negative correlation between accruals and stock returns is determined by inventories investment. Jones and Tuzel (2013), coherently with the view of inventories accumulation as an investment in the same manner as investments in fixed assets, develop a neoclassical model that support the negative relation between the cost of capital and inventories investment. Their study is deeply related to the intuition in Gomes, Kogan, and Yogo (2009) where the durability of output is tied with the firm's cost of capital. Firms with durable output, like firms in the automobile industry for instance, are riskier than firms with non durable products because of the negative correlation between the cost of capital and the stochastic discount factor. The production of durables is very procyclical, this means that more products and profits are realized when the state of the economy is good. Then investing in stocks of firms producing durables entails obtaining positive returns when they are less valuable. This fact leads to lower possibilities of diversification and consequently more risk which translates into higher stock returns. In agreement with the proposition in Gomes, Kogan, and Yogo (2009), Jones and Tuzel (2013) provide empirical evidence on the negative relation between the cost of capital and inventory investment, with cost of capital measured alternatively though analysts earning forecasts or regressions predicting earnings or ROE. They use a sample of firms from a U.S. Census database, integrated with data from COMPUSTAT, for the period 1958-2010. Jones and Tuzel (2013) perform also a classical asset pricing test in which they examine how the risk of stock returns is related to past inventories growth. Portfolios of stocks sorted on past inventory investment display a significant premium between firms with low inventory growth and firms with high inventory growth. Their results are consistent to those found in the work of Belo and Lin (2012) who adopt a theoretical framework very similar to the one in Jones and Tuzel (2013). Belo and Lin (2012) match business cycles and asset pricing stylized facts on inventories through a neoclassical model of investment with fixed capital and inventories as production factors. As for business cycle facts, their model reproduce the stylized positive correlation between sales and inventories investment. As for asset pricing, they perform a portfolio asset pricing test on monthly stock returns for a sample of U.S firms in the 1965-2009 period. Double-sorting portfolios on past inventory investment and size, they find, in agreement with those in Jones and Tuzel (2013), a negative correlation between the investment in inventories and stock return risk. Their empirical results are replicated with simulations of their model.

1.2 Risk Management Literature

1.2.1 Risk Management

The risk management literature provide several motives for firms to hedge. Stulz (1984) argues that in a Modigliani-Miller world hedging does not increase firm value because investors can hedge on their own without having firm's managers doing it. However, when risk averse managers are remunerated with compensation schemes tied to firm value and face transaction costs related to hedging, they may find optimal, for themselves but not for shareholders, to hedge through the firm. The theoretical arguments in Stulz (1984) are derived from the optimization of static model in continuous time where it is shown how optimal hedging does not depend on the firm's exposure to risk but instead on manager's hedging transaction costs. DeMarzo and Duffie (1995) stress the importance of good accounting standards to clearly disclose hedging activity implemented by managers in order to understand if the manager is acting in the interest of shareholders. Smith and Stulz (1985) proposes that the presence of both taxes and bankruptcy costs are good reasons to hedge. They develop a static model in which after-tax income is a concave function of pre-tax income because of convex taxation. Then, in order to reduce tax payments, firms should hedge to reduce to volatility of pre-tax income. Such a beneficial effect of hedging with respect to taxes derives from taxation codes that typically incorporate losses offset provisions and make the corporate tax function convex in pre-tax earnings. Also bankruptcy costs make the after-tax income become a concave function of pre-tax income so that the firm hedge in order to reduce pre-tax income volatility and, consequently, the probability of incurring bankruptcy costs. Smith and Stulz (1985) underscore that also distress costs are a main determinant of hedging basically for the same reasons explained for taxes and bankruptcy costs. Specifically, firm value is increased by hedging thanks to the avoidance of financial distress which generates deadweight costs, like fire-sales or external finance costs,[3] and bounds debt capacity, which in turn leads to a reduction of tax benefits of debt and increases agency costs, given the market discipline provided by debt. Firms in financial distress are exposed not only to direct losses of value but also to agency issues between shareholders and debtholders. According to Myers (1977), in a situation of financial distress, shareholders may be less inclined to undertake positive NPV investment projects if the benefits from such investments primarily accrue to debtholders.

Froot, Scharfstein, and Stein (1993) provide a rationale for hedging on the basis of capital market imperfections that significantly affect real investment decisions. If it is costly for the firm to raise external finance, hedging reduce the probability of incurring direct costs of external finance. Moreover, with hedging firms can also avoid underinvestment costs. Technically, external finance costs make the firm's profits a concave function of internal funds so that hedging helps to mitigate incurring costs deriving from a shock to internal funds. Froot, Scharfstein, and Stein (1993) add that, in a framework with stochastic investment opportunities that are positively correlated with cash flows from outstanding assets, there is less need for hedging. In that situation, when cash flows are low, investment opportunities are less attractive so there is less need of funds to be invested and the firm automatically avoids external finance costs. Froot, Scharfstein, and Stein (1993) take into account also the fact that the external finance costs may be a negative function of the shock moving the cash flows. This means that there is an high probability that the firm will incur external finance costs when cash flows are negatively shocked. In that event, hedging is more valuable. Finally, Froot, Scharfstein, and Stein (1993) discuss the potential drawbacks from hedging plans. Firstly, firms adopting linear hedging

[3]Technically, external finance costs arise when uses exceed sources of funds, also in situations of no distress. However, in the event of distress, the firm may obtain additional financing to avoid distress if external finance costs are sustainable.

through the trading of forward or futures contracts are exposed to contingent payments to the counterpart in the contract. For example, consider an airline company that has hedged against fuel price with a long position in futures whose underlying asset is positively correlated with fuel price. Given the symmetric nature of the payoff, firm with position in futures, avoids external finance costs when cash flow is low, because of high fuel price, and cash is gained from the derivative. However, the firm cannot exclude the possibility of lower profits due to obligations in the futures, or forward, when the state of the cash flow is good and the futures pays off to the counterpart. Then, Froot, Scharfstein, and Stein (1993) suggest that options can be more effective risk management tools than futures. Secondly, a firm may be willing to hedge risks that are only weakly correlated with those traded in financial markets. This possibility creates a substantial basis risk that invalidate the performance of hedging. Thirdly, the product market competition extends to hedging in such a way that firms hedging decisions depends also on rivals' hedging decisions. This happens because if hedging provide a firm with additional funds to be invested, rivals should plan to hedge as well in order not to lose product market share.

Risk management theory suggests that firms with more debt should hedge more because fixed interest payments amplifies the effects of cash flow volatility through leverage effect which in turn increases the probability of incurring financial distress costs. Stulz (1996) and Leland (1998) emphasize that hedging increases firm value because it makes possible to increase debt capacity and thereby interest tax deductions. Leland (1998) underscore that hedging increases firm value through two different channels. The first channel relates to the possibility to increase debt and so interest tax benefits, the second channel pertains to the reduction of expected distress costs and default because of the reduced probability of incurring such events. The effect of increasing debt capacity has also the benefit of reducing agency conflicts between managers and shareholders because of the discipline that debt provides. Hedging provide discipline to managers also in a more direct manner. DeMarzo and Duffie (1995) show that hedging improves the ability to evaluate firm's management given the reduction of noise of measures of profitability, say the volatility of cash flow. However, DeMarzo and Duffie (1995) add that the power of hedging to mitigate asymmetric information costs is deeply conditioned by the transparency of accounting disclosure.

One of the most important recent theoretical contributions to the risk management literature is surely the study of Rampini and Viswanathan (2010). One of the crucial points of their theory is the recognition of a trade-off between hedging with derivatives and debt financing. Also Mello and Parsons (2000) recognize the costs of derivatives in terms of resources required to sustain the hedging policy. Both derivatives and debt contracts require promises of payments that the firm must contemporaneously satisfy if the firm engage in both risk management and debt financing. Consequently, current decisions on hedging and financing policies reflect this future trade-off and eventually lead firms to give up risk management if they already have exhausted their debt capacity. This intuition makes the theory in Rampini and Viswanathan (2010) coherent with empirical findings on the scarce use of derivatives by financially constrained firms. In their model the fundamental piece that connects risk management and financing is counterparty risk in the form of collateral requirements imposed by creditors or risk management counterparts. In addition, the negative relation between risk management and leverage is exacerbated by budget constraints concerns if the firm has good investment opportunities. This result derives from the trade-off between risk management and investment opportunities that is more likely to explain why virtually all empirical studies on hedging found a positive relationship between size and risk management. Indeed, derivatives require down payments when the firm enters the contract. These payments are, for example, margin requirements for derivative trading on exchange markets or option premiums. Paying for risk management means foregoing investment projects that constitute a substantial opportunity cost especially for more productive firms which are most of the time small firms.

Nance, Jr., and Smithson (1993) test theories on corporate hedging with a sample of survey data on hedging usage complemented with COMPUSTAT relevant items for the year 1986. The main dependent variable in their empirical work is the firm's use of hedging. They employ a logit regression method to identify the main determinants of hedging. They find that firms with more investment tax credits in 1986 and with taxable income in the progressive region of the taxation schedule hedge more in agreement with theories postulating that convex corporate taxation induces hedging. In addition, they find that larger firms and firms with more growth opportunities (proxied by R&D expenses) and higher payout ratios do hedge more. Firm's size is positively related to hedging because of a reduction in the expected value of financial distress costs due to the better liquidability of assets. In addition, Mian (1996) report evidence supporting scale economies relative to trading transaction costs and informational costs. The measures of leverage used in Nance, Jr., and Smithson (1993), interest coverage ratio and debt ratio, are, however, found not significant even if they report the correct sign on the estimated regression coefficients.

Tufano (1996) empirically examines the gold mining U.S. industry in the years 1991-1993 relying on data from an equity analyst report. Using tobit analysis with delta-percentage[4] as

[4]Delta-percentage is defined as the Black and Scholes (9173) delta divided by the size of the exposure to

the dependent variable, Tufano (1996) finds little evidence for the Froot, Scharfstein, and Stein (1993) arguments that relates external finance costs to hedging. However, Tufano admits that such costs are less likely to be relevant in the industry studied. On the other side, Tufano reports that managerial risk aversion plays a significant role in shaping risk management policies. He finds that firm managers holding compensation schemes with a large component of convex remuneration implement less hedging. Conversely, managers who hold firm's stocks are more prone to engage in hedging because of the possibility of incurring losses due to directional risk. Another important result in Tufano (1996) is the significant negative relation between hedging and other financial policies considered as substitutes. For example, firms with higher ratios of liquid assets tend to hedge less.

Gézcy, Minton, and Schrand (1997) provide empirical evidence on the predictions of the theory of Froot, Scharfstein, and Stein (1993). They find that firms with good investment opportunities and that are more financially constrained are more likely to hedge. They study foreign exchange risk hedging in a sample of *Fortune 500* firms in 1990. The channel through which hedging acts is primarily the reduction of the likelihood of incurring downside costs that may obstruct investment opportunities. In addition, they find evidence on the increase of foreign exchange risk hedging in relation to the concomitant implementation of other hedging polices related to other risks. This result supports the evidence in Mian (1996) of the presence of economies of scale in the use of derivatives.

Graham and Smith (1999) analyze the tax-incentive to hedge. They highlight a common problem for those who engage in empirical studies on hedging: the scarce reliability of data on derivatives usage. Aware of this problem they adopt a simulation method to measure the convexity of the tax function for a sample of COMPUSTAT firms in the period 1980-1994. The tax function delivers the firm's expected tax liability given taxable income. Graham and Smith (1999) estimate the tax function and simulate firm's taxable income to determine the expected tax liability. They perform this exercise for different levels of the taxable income volatility to gauge the magnitude of tax savings due to hedging. Their results indicate that tax savings, induced by reduced taxable income volatility, average around 1% given a 1% decrease of taxable income volatility. However, they point out that the tax incentive to hedging is relevant only for small to medium size firms with high taxable income volatility and with average taxable income equal to zero, a region of taxable income where the tax function is convex for all firms.

The tax incentive to hedge does not act only through the convexity of the tax function but also through debt tax shield. Graham and Rogers (2002) perform an empirical study to discrim-

risk.

inate which type tax incentive is relevant for firms to undertake hedging. Graham and Rogers (2002) estimate a structural model by means of simultaneous equations approach in which derivatives usage and debt ratio are the two dependent variables of interest. Derivatives usage is measured through notional on derivative positions taken from SFAS 119 descriptions. The simultaneous equations approach is suggested by the possible bi-directional causality between hedging and debt. Graham and Rogers (2002) provide evidence on the positive relationship between hedging and debt and on the reverse causality between these two policies. Specifically, their results are supportive of theories that emphasize an incentive to hedge to increase debt and consequently interest tax deductions. In addition, they find that the interest deduction tax benefit in percentage of firm's assets value averages 1.1% in agreement with numerical results in Leland (1998).

Rampini, Sufi, and Viswanathan (2014) empirically examine the theory developed in Rampini and Viswanathan (2010). They construct and empirically test a model in which firms optimally manage real investments, leverage and hedging. More specifically, firms can hedge operating costs using a forward contract. The model is tested on a sample of 23 U.S. airlines between the years 1996 and 2009. The main results indicate that firms sample firms use hedging with derivatives conditional on net worth, say, the sum of internal funds and liquidation value of assets. This result is in agreement with other empirical previous works where larger, liquid and profitable firms are found to rely more on financial hedging. In contrast, smaller firms prefer not to use derivatives because of the high opportunity costs given by forgone investment opportunities. Rampini, Sufi, and Viswanathan (2014) match empirical tests with anecdotal evidence taken from firms 10-K SEC filings where managers express great concern on the difficulty of engaging in risk management because of the obligations required in derivatives contracts.

Starting with the study of Allayannis and Weston (2001) empirical studies in risk management examine the impact of hedging activity on firm value. Allayannis and Weston (2001) test the relation between the hedging activity of foreign exchange risk and firm value in a sample of U.S. non-financial firms for the period 1990-1995. They find that hedging positively impacts firm value with an the average 5% increase in Tobin's Q for hedgers. Carter, Rogers, and Simkins (2006) examine the relation between hedging activity of fuel cost and firm value measured by Tobin's Q in a sample of U.S. airlines between 1992 and 2003. They find an even larger hedging premium, between 5% and 10%, than Allayannis and Weston (2001) and provide support for the predictions in Froot, Scharfstein, and Stein (1993) on the positive relation between hegding and future investment opportunities. Their basic argument is that airlines will benefit from hedging because when they need to invest it is quite likely that they will experience high fuel costs that reduce internally generated funds from assets in place leading the firm to bear external finance costs.

Guay and Kothari (2003) challenge the validity of the empirical results obtained in previous studies on the effect of derivatives on firm value. To be specific, Guay and Kothari (2003) point out that the magnitude of the effect of hedging with derivatives on firm value is very small. They provide evidence on their claim by examining the hedging policy of a sample of 234 large U.S. firms for the fiscal year 1997. The basic point in Guay and Kothari (2003) is that the magnitude of the effect of derivatives on firm value, reported in many studies like Allayannis and Weston (2001), hardly reconciles with the actual exposure firms have on derivatives. Exposure is computed as the cash flow sensitivity and value sensitivity of the firm's derivatives portfolio to an extreme variation of the underlying assets in such a portfolio. This exposure is then scaled by the variables, like operating cash flow or value, that the firm wants to hedge. Guay and Kothari (2003) find so small hedge ratios that the use of derivatives is unlikely to determine a significant effect on either operating cash flow or value. Consequently, Guay and Kothari (2003) argue that the increase in firm value due to derivatives, reported in other studies, may be spurious and it may also be deeply affected by other operating hedging strategies that are typically positively correlated with financial hedging. Guay and Kothari (2003) report also empirical evidence supporting existing theories on hedging in the proposed relationships between, for example, size, leverage and growth opportunities and the use of hedging. Leveraged firms and firms with good investment opportunities are found to hedge more because of having, respectively, more chances to incur financial distress and more investment opportunities to be financed without incurring external finance costs.

In addition to Guay and Kothari (2003), also Jin and Jorion (2006) cast doubts on the findings in Allayannis and Weston (2001) and Carter, Rogers, and Simkins (2006) providing argument similar to Guay and Kothari (2003) and pointing out that q-ratios can be affected by many factors that may make the positive relation between hedging activity and firm value spurious. In previous empirical studies the magnitude of the effect of hedging on firm value, when statistically significant, seems influenced by other firm's policies not controlled for. For instance, q-ratios vary substantially across industries so that hedging activity may be associated to higher q-ratio just because we compare firms in different industries that at the same time may adopt, however, different hedging policies. In Jin and Jorion (2006) this concern is mitigated by the selection of firms belonging to the same oil and gas extraction industry where there is also a wide variability in hedging activity. In contrast to Allayannis and Weston (2001) who study only large firms, Jin and Jorion (2006) analyze also small firms that are adequately represented in their sample. Jin and Jorion (2006) define hedging activity as the aggregate delta of firm's derivatives portfolio scaled by either production volume or oil/gas reserves. They find a statistically significant effect of hedging activity on firm's sensitivity to oil or gas prices. However, the impact of hedging on firm value, measured with three different proxy of q-ratio and controlling for other factors that affect the q-ratio, is statistically not significant and even negative. These findings hold for both cash flow hedging and value hedging.

Endogeneity, as in many other areas of study, is a typical concern in empirical risk management studies. Aware of this issue, more recently, Pérez-González and Yun (2013) exploit an exogenous event like the introduction of weather derivatives in 1997 in the U.S. to assess the impact of hedging on firm value. Their point is that firms that were highly exposed to weather risk before the introduction of weather derivatives are more likely to benefit from hedging. In agreement with this argument, they find an average hedging premium of 6% approximately. Also in this study the proxy for firm value is Tobin's Q. Similarly to Pérez-González and Yun (2013), Cornaggia (2013) employs an exogenous event to gauge the impact of the use of hedging on firm value through the channel of productivity. Cornaggia studies the effect on productivity of U.S. agricultural producers of the introduction of a new revenues insurance contract in 1997. He finds that producers who engaged in the new insurance program increased their productivity measured by crop yield. Cornaggia emphasizes that productivity is a channel though which risk management positively impacts real assets and thereby firm value.

In Guay and Kothari (2003), one of the main concerns about the economic significance of hedging activity on firm value is on the possibility that firms may engage in other policies positively related to financial hedging. Consequently, endogeneity may significantly affect the results of studies that do not control, for example, for forms of real hedging. Pantzalis, Simkins, and Laux (2001) examine the effect of operating hedging on firm's exposure to exchange rate risk. More specifically, they study if firm's international network of subsidiaries impact firm's exposure to exchange rate risk. The main independent variables in their regressions are the breadth and depth of firm's international network of subsidiaries, which measure operating flexibility. For example, firms with many subsidiaries in several countries are more likely to offset the negative impact of exchange rate risk on cash flows. This happens because these firms can move production, sales, marketing activities etc. more easily than firms with subsidiaries concentrated in few countries or that operate domestically. Exploiting such a flexibility translates into a lower exposure to exchange rate risk. In this study exposure is measured as the regression coefficient of firm's stock returns on the variation of exchange rate controlling for market return. The sample is made by large industrial U.S. multinationals listed on NYSE and

ASE in 1991.

Gézcy, Minton, and Schrand (2006) study the adoption of different risk management strategies implemented by U.S. natural gas pipeline firms between 1978 and 1995 in response to deregulation, started in the end of 1970's, that exposed those firms to quantity and price risks. Gézcy, Minton, and Schrand (2006) find evidence on the suitability of derivatives to hedge price risk while other hedging strategies, like storage, perform better in hedging volumetric risks. Besides derivatives and storage, they also study cash holdings and diversification of line of business and geographic diversification as alternative hedging strategies. Storage of gas, in the same manner as inventories for manufacturing firms, allows firms to avoid to avoid costs of replenishment of reserves and more importantly to avoid costly stockouts. In addition, storage can be primarily used to hedge against volume risk suggesting complementarity with derivatives. Gézcy, Minton, and Schrand (2006) also find that financially unconstrained and profitable firms rely more on storage and cash to manage risks while the opposite types of firms use alternatively diversification or derivatives. Diversification is probably the most onerous hedging strategy. Even if for many firms hedging is not the main objective of diversification, it is an effective instrument to manage risk especially for multinational firms dependent on exchange rate fluctuations.

A series of theoretical and empirical papers find a not perfect substitution effect between operating and financial hedging like, for example, Mello, Parsons, and Triantis (1995) who show a negative relation between the decision to switch production across countries and financial hedging in response to exchange rate risk. Empirically, also Allayannis, Ihrig, and Weston (2001) and Bartram, Brown, and Minton (2010) provide evidence on the complementarity between operating and financial hedging. Mauer and Triantis (1994) theoretically study the interactions between firm's investment and financing decisions. They develop a model in which the firm has the operating flexibility to switch off production if the output price falls below the marginal production cost. They find that operating flexibility significantly contributes to firm value by reducing the probability to incur financial distress. This fact leads the firm to sustain greater debt capacity and consequently to obtain larger tax shield. This benefit from operating flexibility is of course moderated by the cost of switching mode of production and by debt recapitalization costs. The higher the financial flexibility the lower the impact of operating flexibility on firm value. In summary, Mauer and Triantis (1994) provide theoretical evidence on the not perfect substitution between operating and financial flexibility.

MacKay (2003) empirically studies the interaction between real flexibilities and financing. Real flexibilities can be operating flexibilities regarding the volume of production, the optimal mix of production inputs and the degree of reversibility of assets. Real flexibility reduces the exposure to risk affecting cash flows as shown in Tufano (1998) where gold mining firms flexible in adjusting production have lower stock returns exposures to fluctuations of the price of gold. MacKay (2003) find evidence on the interaction between real flexibilities and leverage taking into account also risk shifting and asset substitution. More specifically, MacKay (2003) finds that operating flexibility increases the likelihood of risk shifting thereby leading creditors to cut financing to the firm. In contrast, investment flexibility is positively related to leverage because covenants in debt contract. Also MacKay (2003) documents a negative relationship between real and financial flexibility.

Gamba and Triantis (2014) focus on integrating liquidity, operating flexibility and financial hedging policies in a dynamic framework. Convex corporate taxes and equity issuance costs are two reasons advocated in risk management literature to adopt risk management, however in Gamba and Triantis (2014) the value of risk management in the presence of such frictions is not huge. Instead the will to avoid distress costs jointly with equity issuance costs makes the difference in terms of value increased by risk management. They find that liquidity management is more effective than hedging. The increase in value due to cash is much greater than the one associate to hedging. It must be said also that the effect of hedging on firm value is increasing in the correlation between firm profitability and the underlying asset in the swap. However, even in the case of perfect correlation between firm 's cash flow and derivative's underlying asset, there is substantial space for cash management to increase value. For example, real frictions like switching operation mode costs cannot be covered unless cash is available. Operating flexibility is the dominant tool for value increase. It reduces both the need for cash and the need for hedging. There are some elements, however, like operating leverage that cannot be covered by operating flexibility and cash is needed to hedge from profit losses more likely when operating leverage is high. In summary, also in Gamba and Triantis (2014) there is evidence that real flexibility and financial flexibility are not perfect substitutes and the strength of the correlation between different risk management strategies clearly depends on structural factors like the distribution of stochastic variables, operating and financial overhangs and other real frictions.

1.2.2 Cash Holdings

Among the motives for holding cash, the risk management motive relates to the possibility of holding cash to avoid default costs, distress costs and external finance costs. Once we control for cash required by operations, we are left with cash used for other purposes. This is called *excess* cash in many papers focused on agency conflicts between shareholders and managers. However, this label can be misleading if we take into account other economic mechanisms that influence cash holdings like tax incentives and risk management. In this Section, I review the fundamental contributions in the literature related to cash hold for risk management purposes because that is the field relevant to my research where cash holdings compete with inventories, besides operational arguments. These two working capital items can be substitutes also in the operations of the firm but this is not the focus of the present work.

Kim, Mauer, and Sherman (1998) study the determinants of cash holdings in a dynamic model where the firm invest in real assets, borrow and saves cash. The main determinant of cash holdings are external finance costs given by direct costs of issuing securities, potential agency issues and asymmetric information problems between the issuer and the purchaser of securities. External finance costs are the prerequisite for the "precautionary" and "speculative" motive for holding cash to hold, where the former relates to the benefit of holding cash to face unexpected contingencies, the latter relates to the utility provided by cash to finance future investment opportunities. The precautionary motive for holding cash goes back as far as Keynes (1936) who argued that firms hold cash to avoid transaction costs related to convert non-cash items into liquidity. The main predictions of the model in Kim, Mauer, and Sherman (1998) are tested on a sample of U.S. industrial firms between 1975 and 1994. Empirical results, in which they control for industry effects that proxy for operational motives for holding cash, confirm many relationships that agree with risk management view for holding cash. First of all, Kim, Mauer, and Sherman (1998) find a positive relation between growth opportunities (future investment opportunities), measured with Tobin's Q, and cash holdings. More cash is hold when the firm expects more need to finance investment projects in the future. Secondly, they find evidence on the positive relation between cash flow volatility and cash holdings. Cash flow uncertainty enhances the precautionary motive for hoarding cash by increasing the likelihood of bearing future external finance costs. Finally, the spread between return on assets and the Treasury Bill rate is used to proxy for the opportunity cost of forgone current investment opportunities when the firm decides to save. The larger the spread the lower the incentive to save cash.

Opler, Pinkowitz, Stulz, and Williamson (1999) study the determinants of cash holdings in a sample of U.S. firms between 1971-1994. They find strong support for the transaction cost motive for holding cash early developed by Keynes (1936). In agreement with Kim, Mauer, and Sherman (1998), they find that external finance costs deeply influence firm's cash holding. These costs belong to the category of transaction costs among which there are also asset liquidation costs, underinvestment costs, dividends reductions and debt restructuring. All these sources of funds are costly, therefore it is valuable to save cash to finance future investment opportunities without incurring transaction costs. Opler, Pinkowitz, Stulz, and Williamson (1999), in agreement with the precautionary theory, empirically find that firms with good investment opportunities, smaller firms and firms with very volatile cash flows save more. Small firms typically bear higher external finance costs, consequently they hold more cash. In addition, Mulligan (1997) provide evidence in support of economies of scale in holding cash to avoid transaction costs. Opler, Pinkowitz, Stulz, and Williamson (1999) find also that net working capital (net of cash) is negatively related to cash. Finally, Opler, Pinkowitz, Stulz, and Williamson (1999) find statistically significant mean reversion of firm-level cash holdings time series and little evidence of a joint increase of capital expenditures and cash in relation to theories focused on agency costs. Jensen (1986) argues that managers, to avoid external monitoring, tend to hold excess cash that will be eventually used to finance negative NPV investments projects when managers would better distribute funds to shareholders. Opler, Pinkowitz, Stulz, and Williamson (1999) do not find support for Jensen (1986) theory but they do find that managerial risk aversion, exacerbated by managers' ownership, leads firms to hold excess cash as a risk management tool in the interests of managers rather than shareholders.

Almeida, Campello, and Weisbach (2004) examine the extent to which financing constraints affect the firm's liquidity management. Their study is relevant because of the link between internally generated funds and cash management and because of the provision of a measure of financing constraints in the form of the cash sensitivity to cash flow. As for the first point, they argue that constrained firms should display significant and positive sensitivity of cash to cash flow while cash holdings of unconstrained firms, for which being short of funds is irrelevant, should not be dependent on cash flows. In addition, they argue that the sign of the sensitivity should be positive because firms are more likely to save after a positive realization of the operating cash flow. The second point relates to the fact that the cash sensitivity to cash flow is a better measure than the real investment sensitivity to cash flow simply because the former is unaffected by future firm's economic conditions as it is the latter. They provide evidence for their arguments on sample of COMPUSTAT manufacturing firms between 1971 and 2000. They find that the cash sensitivity to cash flow is positive and significant for constrained firms while it is not significantly different from zero for unconstrained firms. The procedure followed is to sort firms by their likelihood of bearing financial constraint, measured with specific variables provided in the literature,[5] and then to assess the relative sensitivity of cash to cash flow

[5]Kaplan and Zingales (1997) and Whited and Wu (2006) provide measures of financial constraints.

through a simple regression analysis.

Riddick and Whited (2009) challenge the conclusions in Almeida, Campello, and Weisbach (2004) for two reasons. Firstly, it is at least questionable that the cash sensitivity to cash flow is a good measure of financial constraint only because it is not a real variable not correlated with future economic growth of the firm. Indeed, firms save to meet future investment opportunities, then cash is also correlated with future economic growth. Secondly, in the model of Almeida, Campello, and Weisbach (2004) the important link between cash flow and firm's technology is missing. Consequently, any increase in firm' cash flow due to investment in capital is not captured in their model. If cash flow is high and the stochastic factor(s) that moves it is (are) persistent, good investment opportunities are available. Consequently, the firm dissaves, and uses funds to finance current investments, aware that in the next period financing constraints will not bind thereby reducing the advantage of holding cash. Given this second argument, the model in Riddick and Whited (2009) predicts a negative relation between cash flow and savings after controlling for Tobin's Q. The relation between cash flow and savings is tested on empirical data from different countries (U.S., Japan, U.K., France, Germany). Using an estimator robust to measurement error in Tobin's Q, Riddick and Whited (2009) find significant evidence on the negative relation between cash flow and cash for all countries examined.

Gamba and Triantis (2008) study in a dynamic model the value of financial flexibility, say, the value of obtaining funds when the firm needs to finance investments or to avoid distress, without incurring external finance costs. Financial flexibility depends on financial and credit markets frictions as well as on cash holdings. Gamba and Triantis (2008) consider both equity issuance costs and debt issuance costs. The latter crucially impacts the willingness of the firm to tap credit markets to obtain tax shield and to fund investments. Cash is a valuable alternative financing option in presence of debt issuance costs that are the key element that differentiate debt from cash. The value of financial flexibility depends on firm's growth opportunities, taxes and assets reversibility. In an environment where the firm obtains funds with cost, holding cash adds value to the firm. This result is empirically confirmed by Faulkender and Wang (2006) who find that cash holdings are more valuable for firms with good investment opportunities and financially constrained firms. In agreement with Gamba and Triantis (2008) and Bolton, Chen, and Wang (2011), they also find decreasing returns for holding cash. Indeed, if the firm has plenty of cash there very little gain from further savings because of the very low likelihood of incurring external finance costs. Bolton, Chen, and Wang (2011) further explain the real consequences of financing constraints that make cash valuable to the firm. More specifically, they derive that optimal investment is constrained by financial constraints, as in Myers and

Majluf (1984), and that the firm will optimally choose to invest less if the value of cash is high, thereby deciding to save. Similarly to Gamba and Triantis (2008), the question if cash is negative debt is addressed also in Acharya, Almeida, and Campello (2007). In this study, it is shown that even if both cash holdings and debt reductions are substitutes in terms of hedging future downside costs, firm prefer to hoard cash when there is enough probability that future investment opportunities occur in the state of the business in which cash flow is low. The element that differentiate cash from debt is the intersection between hedging needs and financing needs where external finance costs play an important role. Specifically, the firm is indifferent on the choice between cash and debt unless cash flows from asset in place are negatively correlated with investment opportunities so that when cash flow is expected to be low the firm needs funding that can be more easily obtained from existing cash.

Bates, Kahle, and Stulz (2009) document a dramatic increase in cash hold by firms in their sample of U. S. firms between 1980 and 2006. The cash ratio increased from 10.5% in 1980 to 23.2% in 2006. The puzzling fact is that firms should have decreased cash holdings because both firm and financial intermediaries improved the way to manage and reduce transaction costs of financing. However, Bates, Kahle, and Stulz (2009) argue that the secular increase of cash flow volatility, documente in Campbell, Lettau, Malkiel, and Xu (2001) and Irvine and Pontiff (2009), has led firms to increase cash holdings, particularly for nondividend payers firms. This fact brings evidence in support of cash hold for precautionary reasons. In the same period also net working capital (net of cash), especially inventories stock, decreased. Thirdly, net debt (debt minus cash) also decreased in the same period mainly because of the increase in cash holdings. Firms also cut of capital expenditures and increased R&D expenses. Current capital expenditures are in competition with savings in the optimal allocation of firm's resources. R&D expenditures signal higher growth opportunities, say more need of fund in the future, but also more risk and thereby more likelihood to experience distress. Then, firms engaging in research and development activities hold more cash on average. Overall, the evidence in Bates, Kahle, and Stulz (2009) support the transaction costs and precautionary theories for holding cash while agency problems do not appear to be relevant after the authors explicitly control for them. For example, one might argue that nondividend payers firms, with bad investment opportunities, increased cash because of entrenched managers. However, Bates et al. show that also firms with good growth opportunities increased cash holdings. In addition, cash policies do not display significant differences between firms with different levels of the Gompers-Ishii-Metrick index of manager entrenchment.

Denis and Sibilkov (2010) find further evidence on the marginal contribution of cash on firm value. They develop an empirical analysis on a sample of U.S. firms between 1985-2006. Their main findings are that firms hoard cash in response to financing needs to avoid incurring external financing costs. Moreover, they provide evidence on the benefit provided by cash in terms of increased spending in valuable investment projects using a 3SLS estimation procedure that allows to control for endogeneity between savings and investment decisions. Finally, they find that firm with very low cash holdings typically have low operating margins and high capital expenditures.

Also agency conflicts between managers and shareholders play a role in explaining cash holdings. In many studies it is found evidence in this sense. Dittmar, Mahr-Smith, and Servaes (2003) show that firms in countries with poor investors protection hold more cash. Gao, Harford, and Li (2013) confirm this prediction also within U.S. boundaries finding that privately owned firms, less subject to agency conflicts, hold less cash holdings. Turning the attention to the effect of agency issues to firm value, Dittmar and Mahr-Smith (2007), Pinkowitz, Stulz, and Williamson (2006) and Nikolov and Whited (2014) support theoretical arguments on value destroying mechanisms in firms more exposed to agency issues. The literature provides also reasons related to taxes and market-timing to explain high cash holdings. For example, Foley, Hartzell, Titman, and Twite (2007) find that U.S. multinationals tend to hoard piles of cash abroad because of repatriation taxes. Bolton, Chen, and Wang (2014) tie the decision to hoard cash to stochastic financing conditions arguing that firms, instead of saving, may prefer issue external finance when this is cheap. They basically propose a time-varying benefit for holding cash according to the different magnitude of financing costs that firms face in different periods. Agency costs, taxes and market timing are all important factors that affect cash holdings. However, for pertinence and tractability reasons, I only focus on the risk management perspective.

1.3 Theories on Trade Credit

In this Section I review of the main theoretical contributions that explain the existence of trade credit.[6] Literature on trade credit basically starts in the macroeconomic framework with the works of Meltzer (1960) and Brechling and Lipsey (1963) where particular attention is devoted to the study of the effectiveness of the monetary policy. The premise of this early literature

[6]With trade credit I refer to credit granted (accounts and notes receivable, AR) and received (accounts and notes payable, AP) resulting from supplier-buyer commercial deals. In what follows I define firms granting credit as *sellers* or *suppliers* and firms receiving credit as *buyers* or *customers*.

is the existence in the economy of large highly liquid firms with easier access to traditional financing that grant credit to smaller firms when funds are scarce in the financial system. A restrictive monetary policy reduces resources available in financial markets to the point where financially constrained firms cannot finance new investment projects. Meltzer (1960) argues that the allocation of funds from larger to smaller firms neutralizes the impact of tight monetary policies. Brechling and Lipsey (1963) refine Meltzer proposition postulating that the presence of trade credit in the economy leads to a relaxation of the effects of monetary policy only when receivables are financed with cash. On the other side, when suppliers finance trade credit with the sale of assets a deflationary effect is produced that reinforces the restrictive monetary policy. White (1964) confirms Brechling and Lipsey (1963) predictions but he adds that although trade credit may act against the direction of monetary policies such effect is not enough to nullify the anti-inflationary force of restrictive monetary policies. Laffer (1970) strengthens the conclusions in Meltzer (1960) underscoring the role of unused trade credit as a significant component of money stock jointly with cash and bank accounts. Then, money and trade credit are seen as substitutes methods of payment. Nadiri (1969) formally develops the point in Meltzer (1960) on the productivity of trade credit for the supplier. Specifically, Meltzer (1960) sees trade credit as a way for suppliers to increase sales by taking advantage of liquidity needs of customers. Nadiri (1969) considers trade credit as an expense that, in the same manner as advertising, enhances the supplier's product demand. The increase in sales provided by trade credit compensates the costs of lending given by the opportunity cost and possible missed repayment of debt by customers.

Schwartz (1974) introduces a pure financial motive for granting trade credit. Schwartz's work hinges upon one of the main assumptions of early literature on trade credit and monetary policy, say, the existence of firms with easier access to financing like bank loans and the recognition of trade credit as a mean of payment. Another important building block behind Schwartz's theory is the evidence on credit rationing that negatively impacts riskier firms financing (Jaffee and Modigliani (1969)) and creates a demand for trade credit. According to Schwartz, liquid suppliers extend trade credit only when the return exceeds the the cost of forgone current payment of products and the increased marginal cost production represented by the cost of granting credit.

A series of studies concentrate on financial markets imperfections to explain the existence of trade credit. Lewellen, McConnell, and Scott (1980) state that trade credit is irrelevant in a Modigliani-Miller world. Information asymmetries between firms and financial institutions design a specific role for trade credit that is granted by supplier that have more information on buyer's creditworthness because of the trading relationship. Suppliers can lower the costs of granting credit because of their better enforceability of credit with respect t financial intermediaries. Ferris (1981) proposes a transaction costs motive for both suppliers and customers for engaging in trade credit agreements. On the customer side, the possibility to detach the moment of the purchase from the moment of payment of products contributes to the reduction of transaction costs like forced assets liquidation. On the suppliers side, there is a reduction of costs related to the factoring of receivables. In sum, organized payments decrease incurring in deadweight costs deriving from a mismatch between real operating needs and financial obligations. Brick and Fung (1984a,b) examine the impact of taxes on trade credit without recourse to credit market or payment financial imperfections. Specifically, Brick and Fung (1984b), assuming accounting on cash basis, demonstrate that a convenience for trade credit, as opposed to immediate payment, as long as the tax shield earned by customer firm for immediate payment is lower than the tax shield implicit in the repayment of trade credit. Emery (1984) recognizes two motives for credit extension from suppliers. Firstly, from the supplier point of view, trade credit is an operating flexibility tool that can be used to tune product demand by varying the credit contact terms. For example, lowering interest rate or lengthen credit period for the same interest rate may convince the customer to buy products. Secondly, Emery (1984) regards trade credit as a value enhancing instrument as long as it helps to reduce the spread between borrowing rates and lending rates on credit markets. Smith (1987) develops a static model focusing on the interest rate charged in trade credit contracts as a screening device to detect buyers' creditworthness. In this sense there is no difference between a supplier and a bank about credit provision. However, Smith (1987) proposes that the interest rate on trade credit is lower than the one on bank loans because of supplier's asset specificity, for which the supplier is willing to apply a low cost on credit to salvage his or her investment.

Meltzer (1960), Schwartz and Whitcomb (1979) , Mian and Smith (1992) propose that suppliers use trade credit to price discriminate between buyers. Brennan, Maksimovic, and Zechner (1988) develop a model based on suppliers' market power and the presence of buyers with different creditworthness. The supplier can discriminate between rich and poor buyers by means of trade credit thanks to the unelastic product demand in the trade credit market. Basically, poor or risky buyers cannot afford to buy supplier's product with cash because of lack of funds so they can only buy on credit. The interest rate charged on the credit contract is such that the supplier will extract all the surplus from future income of the poor buyers. In this way the supplier can charge rich buyers with an higher cash price and at the same time can offer trade credit to poor buyers at an interest rate typically above the risk free rate. Brennan, Maksimovic, and Zechner (1988) rely on strong assumptions like suppliers' market power and the degree of financial constraints suffered by customers. However, Klapper, Laeven, and Rajan (2012) find that also large and creditworthy firms demand trade credit.

Lee and Stowe (1993) propose a model in which customers decide the amount to be purchased on account versus cash payment. The buyer is exposed to a trade-off between the will to inspect the quality of the product purchased and the higher price that must be paid if a trade credit is started. Conversely, if immediate cash payment is chosen, the price paid is lower but the buyer is left exposed to the product quality risk. Lee and Stowe (1993) assume that the supplier's product quality is exogenously given so extending credit to the customer with a discount provision for immediate payment let the supplier share risk with the customer.

Demirguc-Kunt and Maksimovic (2001) and Fisman and Love (2003) emphasize the characteristics of the wide economic environment that lead to the use of trade credit. The level of development of financial markets contributes to the overall economic growth of a country. Then, in less developed countries, where the financial market cannot reach many small and riskier firms, trade credit represents an effective instrument to allocate funds also to those firms. Secondly, Demirguc-Kunt and Maksimovic (2001) provide evidence on the complementarity between bank credit and trade credit in countries where the cost of providing credit are high for banks. For example, in countries with laws that prevent banks from holding large stock shares in firms monitoring costs are higher. In this case, suppliers may provide credit demanding an interest rate on trade credit lower than the prevailing bank loan rate because of the better ability to monitor customers. Coherently, Demirguc-Kunt and Maksimovic (2001) and Fisman and Love (2003) conclude that trade credit and banks credit are complementary.

Petersen and Rajan (1997), Frank and Maksimovic (2004), Burkart and Ellingsen (2004) and Fabbri and Menichini (2010) focus on firm-specific characteristics that lead suppliers and buyers to stipulate trade credit contracts because of the reduction of credit enforcement costs. Frank and Maksimovic (2004) argue that the buyer's collateral quality is a key driver for trade credit. Suppliers offering standardized products bear lower credit costs. They can easily resell products to other customers after collection from defaulting buyers. This proposition is reinforced by Petersen and Rajan (1997) findings that firms with a high percentage of finished good inventories systematically obtain less trade credit than otherwise identical firms. Indeed, the more a product goes through the production process the harder is to resell it because of the loss of standardization. Fabbri and Menichini (2010) confirm the role of collateral as a crucial determinant of trade credit. They argue that suppliers' liquidation and informational advantages, over traditional banks, contribute to the existence of trade credit. The liquidation advantage pertains to the possibility for the suppliers to resell collateral through selling channels. Liquidation of goods is much more costly for banks. The informational advantage relates to Burkart and Ellingsen (2004) intuition on the nature of trade credit: unlike cash, goods cannot be diverted. This advantage increases the recovery value of trade credit for the suppliers. In contrast, financial intermediaries cannot lend goods but only liquidity that can be more easily diverted.

Cunat (2007) focus on the value of the trading relationship between supplier and customer as a crucial determinant of trade credit. Buyers with supplier-specific assets cannot change supplier without cost so they are more prone to repay trade debt. On the other side, the supplier, who cares on the future revenues from the trading relationship, not only is eager to extend credit but he/she also allows the buyer to postpone credit repayment, when the buyer is temporarily financially constrained. This practice is empirically found also by Boissay and Gropp (2007) in a sample of French firms. Of course, postponing the repayment of debt means a cost for the supplier for which it must be compensated. Such cost is included as an additional premium in the interest rate charged in trade credit contracts.

Chapter 2

The Value of Inventories Management

2.1 Introduction

Inventories play a prominent role in business cycle fluctuations, accounting for the most part of GNP variations as reported in Blinder and Maccini (1991). More recently, Alessandria, Kaboski, and Midrigan (2010) find similar patterns also for the economic crisis of 2008-2009 in the United States. Carpenter, Fazzari, and Petersen (1994) document a strong positive correlation between inventory investment and operating cash flow. Firms adjust inventory very quickly in response to cash flow shocks because of the higher liquidation value compared to fixed assets.

Even though previous literature highlights the role of inventory as an effective source of liquidity, there are significant costs associated with carrying inventory thereby supporting a drastic reduction of the stock of inventory to improve operating margins. A supply chain manager interviewed in Manuj and Mentzer (2008) as part of their qualitative study, defines inventory as a “no brain” and inefficient tool to manage risk, given its cost. Surely, starting from the early 1980’s, many technological advancements contributed to a secular decline of inventory holdings, documented for the U.S. by Bates, Kahle, and Stulz (2009) among others. For example, the adoption of just-in-time production, IT systems innovations, practices of vendor managed inventory and deregulation of the transportation sector made the flow of materials along supply chains more efficient. In the same period, firms also started to focus on different strategic plans like outsourcing with reliance on multiple suppliers, transforming supply relations from adversarial to cooperative as reported in Helper (1991) and product diversification.

In contrast to these views mostly concerned with efficiency rather than risk management, Juttner, Peck, and Christopher (2003) highlights the importance of mitigating operating risks with suitable risk control strategies among which inventories management plays a crucial part. In support to this view, Chen, Frank, and Wu (2005) empirically demonstrate that low inventories holdings are not associated with better financial performance. In addition, in their sample of U.S. manufacturers between 1980 and 2000 average stock of the input inventories has declined while output inventories did not. Moreover, although many technological and regulatory innovations improved firm's efficiency, they also contributed to expose firms to new market risks. For instance, deregulation intensified competition in many sectors. Gézcy, Minton, and Schrand (2006) underscore how natural gas pipelines needed to take risk management into serious consideration to face exposures to risks spurred by the creation of competitive markets by deregulation. As another example, outsourcing has become more internationally focused to the point that firms are more exposed to political and operational (logistic) risks. Transportation costs are still a big concern for global supply chain managers interviewed in Manuj and Mentzer (2008). Overall, domestic and global competition also increased in the last decades, as underscored by Blinder (2000) and Bils and Klenow (2004). Competition stimulated demand volatility contributing to the increase of the average firm's sales volatility, as reported by Comin and Philippon (2006), and consequently to the increase of cash flow volatility. In efficient markets, cash flow volatility is turned into stock returns volatility as Campbell, Lettau, Malkiel, and Xu (2001) and Irvine and Pontiff (2009) show. In this sense, Irvine and Pontiff (2009) provide evidence that product market competition is a major determinant of stock returns volatility.

Given the increased cash flow volatility, firms implement several risk management strategies among which inventories management remains a valuable option. Here, I examine the contribution to firm value of inventories through the cash flow hedging channel along with more obvious risk management tools like derivatives and cash holdings and I explain under which circumstances firms would rely more (or less) on inventories rather than derivatives and cash holdings.

Following MacKay (2003), I classify inventories management as *real* flexibility as opposed to financial flexibility, which is achieved with cash holdings or derivatives. Real flexibility can be decoupled in operating flexibility and investment flexibility. inventories provides *substitution* flexibility, a form of operating flexibility which constitutes the actual return from the investment in inventories. Substitution flexibility relates to the possibility of inventories to substitute for other production factors in the event of any operating shock that impede firms to satisfy the demand of their product. In my model, I model substitution flexibility in reduced form.

The contribution of substitution flexibility to the value of risk management is gauged through its effect on cash flow. The concept of substitution flexibility is explained in Ramey (1989) where inventories are considered as a production factor in the same manner as fixed capital and labor. The view of inventories as a production factor is also considered in Kydland and Prescott (1982), Kahn (1987) and Christiano (1988). According to this view, inventories enhance firm value through the flexibility of substitution with other factors of production. For example, firms holding input inventories avoids production disruptions due to supply chain shocks that negatively impacts the quantity and quality of production inputs. Moreover, stopping production leaves capital and other production factors idle thereby increasing the actual opportunity cost of the stop, as pointed out by Ramey (1989). In addition, firms holding input inventories avoid ordering materials too frequently. Besides avoiding ordering transaction costs, this fact leads to employ workers in other more productive activities rather than the preparation of delivered materials for production. Work-in-process inventories are important when firm faces production set-up cost due to a reschedule of the production process. In this event, it is convenient for the firm to hoard work-in-process goods that would be finished when production is activated, thereby increasing productivity. On the output side, in the event of a production disruption or unexpected product demand increases, firms can continue to satisfy demand relying on output inventories.[1] Output inventories also helps reducing the number of deliveries of finished products to customers which means employing workers elsewhere. Finally, firms holding inventories save on transaction costs by avoiding ordering inputs and delivering output too frequently, as remarked in Fisher and Hornstein (2000) and Khan and Thomas (2007). The convenience of holding inventories, inclusive all the benefits described above, is considered in reduced form also in the neoclassical modeling approach I follow and adopted in recent asset pricing contributions on inventories investment like Belo and Lin (2012) and Jones and Tuzel (2013). More specifically, the return from investment in inventories, in terms of marginal productivity, comprises the flexibility of substitution with other production factors.

The macroeconomic literature suggests that another important benefit provided by inventories is the flexibility to adjust the stock of inventories according to the state of the firm's business. Using MacKay (2003) terminology, this benefit relates to the investment flexibility of inventories. Managers confronted with low product demand may want to shut down or reduce production, then they can rely on inventories to satisfy demand. Furthermore, the flexibility of adjusting inventories can be particularly important for firms with high operating leverage

[1] Kahn (1987) proposes a stockout avoidance theory for holding inventories. In addition, Pindyck (1994) provide theoretical and empirical evidence on the convenience of holding inventories in sample of U.S. commodities producers. In his model the convenience of holding inventories includes the avoidance of stock-outs.

and for financially constrained firms for which the bad states of the business are very costly. According to Fazzari and Petersen (1993), if capital markets are imperfect so that external finance is costly, firms reduce the stock of assets in response to a negative shock to cash flow. However, assets differs in remuneration and the degree of reversibility, then inventories are more likely to be divested after a shock to internal funds. Indeed, liquidation of inventories allows to avoid reducing the stock of capital to raise funds. According to Arrow (1968), adjusting capital capacity downward is more costly than increasing it because of liquidation costs. From a risk management point of view, the possibility of divesting inventories can be framed in the work of Froot, Scharfstein, and Stein (1993) as the case in which future investment opportunities are positively correlated with the return from assets in place. In the case of a bad state of the business also investment opportunities are less attractive, then liquidating assets is a convenient way to raise funds without undertaking any other hedging policy. Gertler and Gilchrist (1994), Kashyap, Lamont, and Stein (1994) and Carpenter, Fazzari, and Petersen (1994) all provide empirical evidence in this sense using different measures of financial constraints. Within this view of inventories as a reserve of liquidity there are, however, a few critical points. First, partial irreversibility concretely bounds the effectiveness of inventories liquidation. In addition, the return from outstanding assets is penalized in bad states of the business. Second, inventories investment respond to future revenues so it is possible that, regardless of cash flow, the firm decides to invest in inventories. Reducing investment or even liquidating inventories entails a non-negligible opportunity cost, when they promise a good return. These costs limit the performance of inventories as an hedging tool thereby leaving space for other risk management instruments.

I consider inventories in the context of integrated management along with traditional risk management tools like derivatives and financial slack. Firms manage risk to prevent costs triggered in states of the world in which internally generated funds are scarce. These costs can be external finance costs as in Froot, Scharfstein, and Stein (1993) when firms need to finance investment. Liquidity shortage leads also to distress costs when firms cannot meet operating or financial obligations, as in Smith and Stulz (1985).[2] One of the objective of this study is to assess the contribution of inventories to risk management, in the presence of derivatives and cash holdings. Of course, the interactions between operating and financial flexibilities have been previously studied. Mauer and Triantis (1994) show that production flexibility substitutes for financial flexibility given by the possibility to adjust debt level. Mello, Parsons, and Triantis

[2]Other costs include bankruptcy costs as in Smith and Stulz (1985), the loss of tax shield as emphasized by Stulz (1996) and Leland (1998), information asymmetries costs in DeMarzo and Duffie (1995), underinvestment in Froot, Scharfstein, and Stein (1993).

(1995) also find a substitution effect between the flexibility of moving production between countries and financial hedging. More recently, Bolton, Chen, and Wang (2011) examine the integrated management of real investment, cash holdings and risk management. They first of all show that the marginal cost of investment in real assets, inclusive of possible external finance costs, depends not only on marginal Q but also on the marginal cost of financing. In the model of Bolton, Chen, and Wang (2011) cash, asset reversibility and hedging can be all used to avoid external finance costs. One important point in Bolton, Chen, and Wang (2011) is their recognition of the interactions between financial risk management and operating decisions linked by their role as endogenous sources of liquidity. Bolton, Chen, and Wang (2011) find complementarity between cash holding and hedging with derivatives mainly because of cash acting as collateral for hedging. Secondly, they show that in situations of binding financial constraints firms may prefer to liquidate asset instead of using derivatives to improve the risk management outcome. Disatnik, Duchin, and Schmidt (2014) exploit the difference between cash flow hedging and fair value hedging to study the effect of hedging with derivatives on cash holdings, credit lines and firm value. Concentrating on cash flow hedging they find a significant negative relation between hedging and cash holdings and a positive relation between hedging and credit lines. In their model the explanation for this result derives from the possibility to relax covenants on credit lines with hedging. Covenant relaxation not only allows the firm to rely on credit lines in the future but also to avoid holding cash which is costly. Gamba and Triantis (2014) focus on the integrated management of operating flexibility, cash holding and derivatives from a pure risk management perspective. They find that cash adds significant value to the firm not only by reducing the impact of external finance and distress costs but also by limiting the impact of firm-specific real frictions, costs of switching of operation mode in their model. Secondly, they find that derivatives are very effective only when correlation between operating cash flow and the underlying asset is very high. In those cases, the substitution effect between derivatives and operating flexibility is even more strong.

Empirical studies, like Allayannis, Ihrig, and Weston (2001), Pantzalis, Simkins, and Laux (2001), MacKay (2003), Gézcy, Minton, and Schrand (2006), Hankins (2011) also provide evidence on the negative relation between the use of operating flexibility and hedging with derivatives. One of the key elements that leads firms to choose between operating and financial hedging is the narrow scope that derivatives have to hedge many important risks like quantity or quality risks. Basis risk is an important determinant of hedging ratios a reported in Haushalter (2000) for a sample of oil and gas producers between 1992 and 1994. In contrast to derivatives, inventories can be thought as a customized risk management tool in terms of the better ability to cover firm-specific shocks related, for example, to input supply quantity and quality, machine failures, production adjustment costs and output demand fluctuations. As noted in Mello and Parsons (2000), another important cost associated with the use of derivatives is the counterparty risk compensation required by the counterpart in the contract. This requirement can take the form of a price charge as in Gamba and Triantis (2014) or a collateral guarantee as in Rampini and Viswanathan (2010). Rampini, Sufi, and Viswanathan (2014) provide empirical evidence on the negative effect of collateral constraints on the firm's hedging policy in sample of U.S. airlines between 1996 and 2009.

The overall evidence on the relation between the use of hedging with derivatives and firm value suggest that basis risk and counterparty obligations deeply impact the performance of derivatives. Guay and Kothari (2003) and Jin and Jorion (2006) report a negligible and statistically not significant impact of hedging on firm value. Studies that report a significant effect of hedging with derivatives on firm value typically examine market-to-book variation (Allayannis and Weston (2001), Carter, Rogers, and Simkins (2006) Pérez-González and Yun (2013)) or productivity (Cornaggia (2013)) in response to hedging implementation in regression analysis where endogeneity cannot be fully excluded though. Another important point is that, in the risk management literature, many studies concentrate on very few industries like airlines, as in Carter, Rogers, and Simkins (2006), and commodities, as in Tufano (1996, 1998) and Haushalter (2000). However, I know little on the contribution of hedging to firm value in many important industries like manufacturing or retailing in which investment in inventories is relevant. Disatnik, Duchin, and Schmidt (2014) emphasize that industry effects are important determinants of cash flow hedging implicitly suggesting that results in studies focused on few industries cannot be easily generalized. I contribute to fill this gap by constructing a model suitable also for industries, like manufacturing, to which the risk management literature has reserved little attention.

Bates, Kahle, and Stulz (2009) provide evidence on the secular increase of cash stock held by U.S. firms between 1980 and 2006. Among other factors, the contemporaneous increase in cash flow volatility and the reduction in net working capital, inclusive of inventories, are proposed to explain the trend followed by cash holdings. According to the precautionary motive for holding cash, proposed in Keynes (1936), and empirically tested in Opler, Pinkowitz, Stulz, and Williamson (1999) among others, firms hoard cash in order to avoid distress costs and to take advantage of future investment opportunities without incurring external finance costs especially when cash flows are very volatile. In this study, I argue that the secular increase of cash flow volatility documented in the last forty years,[3] among other factors, contributed to a substitution effect between cash and inventories. One of the economic reasons behind the preference of cash over inventories when cash flow is very volatile is that firms bear liquidation costs also for liquidating inventories. Secondly, the return from inventories becomes more uncertain. For these two reasons, firms may find profitable to save rather than invest in inventories that promise a riskier return and can be liquidated with costs. Also, Han and Qiu (2007), Gamba and Triantis (2008) and Riddick and Whited (2009) provide evidence on the positive relationship between cash flow volatility and cash holdings. For example, Gamba and Triantis (2008) find that increasing the persistence parameter of the productivity shock from 0.62 to 0.85, which translates into higher cash flow volatility, leads to a 60% increase of the cash/value ratio.

The secular increase in cash flow volatility cannot completely explain the decrease of inventories holdings documented in the sample of Bates, Kahle, and Stulz (2009). Other operating and technological changes like the improvements in supply chain management, the reduction of transportation costs, the adoption of different systems of production, like the just-in-time production, may have reduced the contribution of inventories to firm value. Although, also for tractability reasons, I have excluded these operating elements from my study, I can indirectly take them into account thanks to comparative statics on technological parameters that proxy for all technological factors that decrease the relative importance of inventories with respect to other assets. Indeed, if the benefits provided by inventories have become smaller, firms prefer to allocate resources to more remunerative assets and to use alternative hedging tools like cash holdings.

Recently, a few studies have been proposed which are partly related to my work. Dasgupta, Li, and Yan (2014), on the basis of findings in Fazzari and Petersen (1993) and Carpenter, Fazzari, and Petersen (1994), study the relation between financial constraints and output inventories management. In their model, firms invest in inventories when production costs are relatively low and disinvest when production are relatively high, especially when firms face liquidity constraints and capital is costly to adjust. Their main prediction is that financially constrained firms (small firms) vary inventories stock more aggressively than their financially unconstrained counterparts (large firms) in response to production costs. However, they empirically find that financially constrained firms sluggishly respond to positive cost shocks and that both types of firm are not sensitive at all to negative production costs shocks. Their empirical evidence casts serious doubts on the proposed responsiveness of inventories investment to internal funds fluctuations. The message of Fazzari and Petersen (1993) and Carpenter,

[3]See Campbell, Lettau, Malkiel, and Xu (2001), Comin and Philippon (2006) and Irvine and Pontiff (2009).

Fazzari, and Petersen (1994) that, if firms need to cut assets, they will probably start from liquid assets is correct. However, if this need to cut assets coincides with negative shocks to operating cash flows is highly questionable.[4] In the context of my model, this means that firms invest in inventories not in response to cash flow but rather on future revenues they can get by exploiting inventories' operating flexibility thanks to inventories. More clearly, a firm is eager to invest in inventories also when it is financially constrained as long as the return from the investment is higher than the direct cost of the investment possibly augmented with external finance costs. In agreement with this argument from traditional Q theory, Kahn (1987) argues that firms invest in inventories to capture future demand, rather than to save on production costs.

Gao (2014a) proposes that the reduction of input inventories stock and the contemporaneous increase in cash holdings for U.S. corporations can be explained by the adoption of just-in-time production by many firms starting from the beginning of 1980's. Basically, firms adopting just-in-time production do not need to hold inventories because they can buy materials when they need them. In the presence of external finance costs, this leads firms to increase cash holding because of the increased probability of running out of cash to be used to pay materials. In Gao's model firms hold cash only for transaction purposes because there is always a need of cash also in situations of no financial distress or financial constraint typically addressed in the risk management literature. Therefore, in Gao's contribution the choice between inventories and cash can be framed as a operating choice rather than a risk management choice. In another contribution, Gao (2014b) examine how firm's market power in the output product market determines the choice between of output inventories and cash. Assuming an equal degree of liquidity between output inventories and cash, she finds that firms with more market power prefer to invest in inventories rather than hoarding cash because of the possibility to manipulate the return from inventories with pricing power. The inventories's return boosted by market power and no liquidity spread between inventories and cash lead firms to privilege inventories to cash. However, it is at least questionable that inventories and cash share the same degree of liquidity mostly because of inventories adjustment costs. In addition, also in Gao (2014b), the firm's decision between inventories and cash is driven by motivations other than risk management.

Kulchania and Thomas (2014) provide empirical evidence on the sensitivity of cash holdings to exposure to supply chain risk, one of the factors that contributed to the documented secular

[4] Kaplan and Zingales (1997) and Erickson and Whited (2000) question the validity of the sensitivity of investment to cash flow3 as a measure of financial constraints proposed in Fazzari, Hubbard, and Petersen (1988).

substitution between inventories and cash holdings. In their empirical analysis, they find that the negative relation between inventories and cash holdings is exacerbated in presence of proxies of the expected costs of supply chain disruptions. To mitigate endogeneity concerns, they use transportation deregulation in the U.S. as an exogenous factor that allows to isolate the change in inventories not related to endogenous management decisions that involve cash holdings. In this way, they show that the causal relation goes from inventories reduction, due to technological innovations, to cash holdings increases. In both the study of Kulchania and Thomas (2014) and that of Gao (2014a), the focus on is on operating motivations to explain the substitution between inventories and cash holdings. While in Gao (2014a) the reason for holding cash in place of inventories is a transaction motive, in Kulchania and Thomas (2014) cash holdings increased because innovations that reduced inventories left firms exposed to supply chain disruptions. Consequently, cash is used as a production factor in substitution of inventories, independently from risk management concerns.[5]

With respect to previous related contributions, I frame my work in a more general risk management perspective which includes all flexibilities provided by inventories and interactions with derivatives and cash and I exclusively focus on financial motivations for holding inventories. I do not exclude that operating motivations are important to explain inventories behavior but at the same time I isolate financial factors that are valid across different systems of production and above any operating motive to substitute cash for inventories and . Secondly, I take into account the total stock of inventories while most of other studies concentrate only on single components.

2.2 Model

2.2.1 Technology

I consider an all equity financed firm that produces one product using as production factors capital and inventories. I model firm decisions on the integrated management of inventories and financial hedging in a discrete-time infinite-horizon setup with risk neutral agents. Firm's managers, who are aware of the future consequences of current choices, decide investment in fixed capital (only capital in what follows), inventories and either derivatives or cash holdings. I chose the neoclassical modeling approach that allows us to capture both the substitution

[5] The link between supply chain disruption risk and cash holdings is provided in Kulchania and Thomas (2014) with an example on Ford's reaction to increased supply disruptions due to financial distress of its suppliers in 2008. In order to secure input supply, Ford started to provide financing to suppliers thereby reducing cash holdings.

flexibility of inventories and its liquidity component. Following Belo and Lin (2012), the gross profit, or operating cash flow, is

$$f\big(k_t, n_t, z_t\big) = g\big(k_t, n_t, z_t\big) - fc = \big[\alpha k_t^{-\nu} + (1-\alpha) n_t^{-\nu}\big]^{-\frac{\theta}{\nu}} - fc, \tag{2.1}$$

where $z_t > 0$ is a profit shock that determines the state of the firm's business, $k_t \geq 0$ is the stock of capital, $n_t \geq 0$ is the stock of inventories, $\alpha \in (0, 1)$ is the relative contribution of capital to output, $\nu \in (0, \infty]$ is a parameter gauging the degree of complementarity between capital and inventories. $\nu = -1$ implies perfect substitution between capital and inventories while $\nu = +\infty$ implies a Leontief technology where capital and inventories are perfect complements.[6] $\theta \in (0, 1)$ is the return to scale parameter that measures the productivity of assets. fc are fixed operating costs including any operating overhang in the firm's business.

The natural logarithm of the shock $\log(z_t)$ follows an AR(1) process[7]

$$\log(z_{t+1}) = \phi_z \log(z_t) + \sigma_z \varepsilon_t^z,$$

where the autoregressive parameter satisfies $|\phi| < 1$, σ_z is the conditional standard deviation of z_t and ε_t^z are i.i.d. shocks with Normal distribution truncated within three times the unconditional standard deviation. The production function $g\big(k_t, n_t, z_t\big)$ has the usual properties. It is increasing in the technology shock z_t, increasing and concave in both capital k_t and inventories n_t given that $g_k > 0$ and $g_n > 0$ and the associated Hessian matrix is negative definite with $g_{kk} < 0$, $g_{nn} < 0$ and $g_{kk} g_{nn} \geq g_{kn}^2$, where subscripts indicate partial derivatives.[8] The CES specification of the production function assumes inventories as a positive factor of production, which provides a flow of services in the same manner as capital.[9]

[6] $\nu = 0$ coincides with the Cobb-Douglas specification of the production function. The elasticity of substitution is $ES = \frac{1}{1+\nu} < 1$.

[7] The mean reverting process is a standard choice in literature to represent firm specific technology shocks. See, among others, Gomes (2001), Hennessy and Whited (2005), Zhang (2005), Gamba and Triantis (2008).

[8] Pindyck (1994) adopts a *convex* cost function of inventories stock as opposed to a *concave* production function to shape the high convenience value from holding inventories. The results that I obtain, given the differences of the two models, are equivalent. Additionally, Pindyck (1994) empirically finds a significantly convex cost function for the natural resource industries he studied, indicating a strong convenience for holding inventories.

[9] See Kydland and Prescott (1982) and Christiano (1988). The neoclassical production function I adopt is broadly consistent also with standard *production smoothing* theory early developed by Holt, Modigliani, Muth, and Simon (1960) in which firms invest in inventories when costs are low to be able to sustain production in the future. Indeed, production smoothing means investing in inventories when operating costs are low and viceversa. Even if I do not specify a convex production cost function, inventories are increased when the cost of the investment is relatively low with respect to the state of the business. For example, when product demand is high, firms invest in inventories because the cost is low in relation to the benefit they obtain. The opposite happens when the state of business is less favorable.

Excluding asset liquidation, that will be discussed later on, capital and inventories evolve according to the dynamic equations

$$\begin{aligned} k_{t+1} = & \quad (1-\delta_k)k_t + IK_t, \\ n_{t+1} = & \quad (1-\delta_n)n_t + IN_t, \end{aligned}$$

where Ij_t and δ_j, for $j = k, n$, are investments and depreciation rates, respectively, for capital and inventories. Inventories depreciation includes all costs of carry, such as opportunity costs, risk costs (obsolescence, damages, thefts), storage costs and insurance costs. The firm purchases capital and inventories at prices both equal to one if investments are positive, at prices ℓ_k and ℓ_n if assets are liquidated. The investment cost function is

$$\eta_j(Ij, \ell_j) = \begin{cases} Ij & \text{if } Ij \geq 0 \\ \ell_j Ij & \text{if } Ij < 0, \end{cases}$$

for $j = k, n$. As pointed out in Arrow (1968) and Abel and Eberly (1994), firms obtain lower prices when assets are sold because of adverse selection issues in the market of used capital goods or because the assets to be sold are firm-specific. Asquith, Gertner, and Scharfstein (1994) find that in highly leveraged industries firms may find very difficult to resell assets because the likely purchasers of assets are the firm's cash scrapped competitors.[10]

I set ℓ_k and ℓ_n lower than one in agreement with Carpenter, Fazzari, and Petersen (1994), who provide empirical evidence on the relative higher flexibility of adjusting inventories in terms of liquidation costs. For simplicity, I only include in my model the linear component of the investment cost function proposed in Abel and Eberly (1994, 1997). However, I do not ignore the asymmetric nature of the investment cost function emphasized in Abel and Eberly (2002) and Zhang (2005).

2.2.2 Financial Hedging

I separately study the interaction between the investment in inventories and hedging with derivatives and with cash holdings because the integrated management of derivatives and cash has been already analyzed by Mello and Parsons (2000), Bolton, Chen, and Wang (2011), Disatnik, Duchin, and Schmidt (2014) and Gamba and Triantis (2014) and, to some extent, also by Rampini and Viswanathan (2010). My approach allows to genuinely assess the role

[10]Although Asquith, Gertner, and Scharfstein (1994) focus on financially constrained firms, it is reasonable to assume that even if they are not in financial distress, firms with considerable debt or operating overhang would refuse to buy assets at full price.

of inventories from a financial point of view without involving interactions between derivatives and cash holding that may contaminate my results. These interactions may include the will to hold cash in response to possible liquidation costs of assets to meet obligations in derivatives contracts.

Cash flow risk can be hedged not only through the flexibility provided by inventories but also entering a short position in a futures contract with one period to expiration written on a traded asset x_t, which can be thought of as the price of a commodity. Assuming that the firm enters an outstanding contract, I take into account the fact that hedging with derivative may restrict or enlarge the firm's budget constraint. This assumption encompasses a large set of real life cases. For example, a firm close to default may enter the contract only to raise funds regardless of future obligations.

The natural logarithm of the price $\log(x_t)$ follows an AR(1) process[11]

$$\log(x_{t+1}) = \phi_x \log(x_t) + \sigma_x \varepsilon_t^x,$$

where $|\phi_x| < 1$, σ_x is the conditional standard deviation of x_t and $\varepsilon_t^x \sim N(0,1)$ are i.i.d. shocks with Normal distribution truncated within three times the unconditional standard deviation. The stochastic factor ε_t^z driving the technology shock is contemporaneously correlated with ε_t^x so that $\mathbb{E}[\varepsilon_t^z \varepsilon_s^x] = \rho \in [0,1]$ for $t = s$ and $\mathbb{E}[\varepsilon_t^z \varepsilon_s^x] = 0$ for $t \neq s$. Similarly to Gamba and Triantis (2014), an important feature of the model is that the performance of hedging with derivatives crucially depends on the correlation between z_t and x_t. This correlation depends on the extent to which the set of technology risk factors intersects with the set of risk factors traded in financial markets, so that the firm can hedge by buying a derivative contract. The underlying assets of derivative contracts are typically strongly correlated with systematic risk factors while inventories are rather firm-specific. In agreement with these arguments, Disatnik, Duchin, and Schmidt (2014) find that the decision to hedge with derivatives is significantly influenced by industry effects.

The correlation between z_t and x_t may capture also industry-specific characteristics. As pointed out in Gomes, Kogan, and Yogo (2009) and Jones and Tuzel (2013), the qualitative composition of inventories changes across industries sectors generating varying exposures to systematic risk. For example, firms in the extraction and mining industries have inventories that are correlated sometimes perfectly with underlying assets of some commodity derivatives. Conversely, manufacturers hold inventories of goods that in general are not traded in financial

[11] The mean reverting process is a natural choice for a commodity price. See Schwartz (1997).

markets with low correlation with systematic risk factors.

The payoff of the futures purchased at time $t-1$ and expiring at t is $h_t\left(F - x_t\right)$ where h_t is the notional amount and F is the futures price. The price of the futures purchased at t and expiring at $t+1$ is $P(x_t) = \beta\,\mathbb{E}\big[(F - x_{t+1})|\,x_t\big]$, where β is the discount factor. The total cash flow from trading derivatives at t is the difference between the payoff of the outstanding contract and the investment in the new futures contract, $h_t\left(F - x_t\right) - h_{t+1}P(x_t)$, where F is predetermined so that $P(x_t)$ can have either sign. Therefore, the futures can also be a source of funding for $P(x_t) < 0$.

I introduce a collateral constraint for the position in the futures. This is consistent with practices in exchange traded derivatives markets, where collateral in the form of a margin is required.[12] Assuming that cash flows are not pledgeable, as in Rampini and Viswanathan (2010), the collateral constraint is

$$h_t(x_t - F) \leq \ell_k(1-\delta_k)k_t + \ell_n(1-\delta_n)n_t. \tag{2.2}$$

The left-hand side of (2.2) is the payment required to the firm in the event the underlying asset x_t is higher than the forward price F. The right-hand side of (2.2) is the total value of collateral available at expiration of the futures. The maximum possible amount that firm must pay is $h_t(x_u - F)$ where x_u is the assumed maximum possible value that x_t can take. From the collateral constraint I derive the upper bound for the notional amount of the futures $h_u(k_t, n_t) = \big[\ell_k(1-\delta_k)k_t + \ell_n(1-\delta_n)n_t\big]/(x_u - F)$. The lower bound h_l of the notional is zero assuming that no derivatives can be purchased when the firm has no assets.[13]

At expiration of the futures, the firm may not have sufficient internal funds to cover payments in the futures and consequently managers have to liquidate a fraction of the assets. This entails a real cost related to hedging. More specifically, since inventories are relatively more easily reversible and provide a lower return than capital, if the cash flow from operations is insufficient to pay the futures payoff, $h_t(x_t - F) > f(k_t, n_t, z_t)$, the firm will first sell inventories and then capital stock. In summary, the payment $h_t(x_t - F) - f(k_t, n_t, z_t)$ is first covered with the liquidation value of inventories stock $\ell_n(1-\delta_n)n_t$, and for the residual part with a fraction of the liquidation value of capital $\ell_k(1-\delta_k)k_t$. Therefore, the investments in capital

[12] Also in over-the-counter agreements derivatives must be collateralized. For example, the counterpart of the firm in an over-the-counter derivative contract may require a price premium to account for the possibility that in the future the firm may not be able to meet the contingent obligations deriving from the contract. Alternatively, the counterpart may require as collateral a part of firm's assets.

[13] I restrict my analysis, with no loss of generality, to a positive correlation parameter and so the firm will consider taking short positions in the futures, as it is easy to prove. Alternatively, one may consider a long position in a futures contract with correlation parameter $\rho \in [-1, 0]$ to hedge cash flow risk.

and inventories become

$$
\begin{aligned}
IN_t = &\quad n_{t+1} - (1-\delta_n)n_t + \min\left\{ \max\left[\frac{h_t(x_t - F) - f(k_t, n_t, z_t)}{\ell_n}, 0\right], (1-\delta_n)n_t \right\} \\
IK_t = &\quad k_{t+1} - (1-\delta_k)k_t + \max\left[\frac{h_t(x_t - F) - f(k_t, n_t, z_t) - \ell_n(1-\delta_n)n_t}{\ell_k}, 0\right],
\end{aligned}
$$

Liquidation of assets is very costly not only because it weighs down investments/disinvestments but also because it contributes to incur external finance costs.

As an alternative to hedging with derivatives, the firm can hold cash to limit the impact of the costs induced by cash flow risk. In each period, the firm decides to allocate available funds among the investments in capital and inventories or to save it in a money market account in order to meet future potential investment opportunities without incurring external finance costs. On the other hand, cash will be inefficiently held also in states of the world in which cash flow from operations is high. In addition, firm holding cash incur a penalty on its return given by taxes and by agency costs between managers and shareholders. The tax penalty for holding cash is given by the difference between corporate taxes, paid if cash is retained in the firm, and personal taxes charged on investors if cash is distributed. Jensen (1986) underscore that holding excess cash may induce lower monitoring over managers that, in this way, are more likely to invest in negative NPV projects. In my model I do not include tax payments nor agency costs but I do take into account these costs in reduced form by assigning to cash a return r_{cb} lower than the risk-free rate, $r_{cb} < 1/\beta - 1$. Finally, the opportunity costs of investing in more remunerative assets discourages saving in favor of current investment opportunities.

2.3 Firm's Problem

Firm value is the result of the maximization of the present value of an infinite sequence of dividends to shareholders e_t with respect to the control variables k_{t+1}, n_{t+1} and h_{t+1}, or in the version of the model with cash holdings, cb_{t+1} in place of h_{t+1} is replaced by . Dividends can be either positive or negative according to whether the firm pays out or issues new equity. Firm value at time zero is

$$
v(k_t, n_t, h_t, z_t, x_t) = \max_{\{k_t, n_t, h_t\}_{j=t+1}^{\infty}} \mathbb{E} \sum_{i=t}^{\infty} \beta^{i-t} \, e(k_i, n_i, h_i, k_{i+1}, n_{i+1}, h_{i+1}, z_i, x_i), \qquad (SP_h)
$$

if hedging is implemented with derivatives, and

$$v(k_t, n_t, cb_t, z_t) = \max_{\{k_t, n_t, cb_t\}_{j=t+1}^{\infty}} \mathbb{E} \sum_{i=t}^{\infty} \beta^{i-t} e(k_i, n_i, cb_i, k_{i+1}, n_{i+1}, cb_{i+1}, z_i), \tag{SP_{cb}}$$

if cash holding is a control variable in place of hedging. More compactly I indicate endogenous state variables with $u = (k, n, h) \in U_h$ or with $u = (k, n, cb) \in U_{cb}$ in the second version, and exogenous stochastic state variables with $s = (z, x) \in S_h$ or with $s = z \in S_{cb}$ in the second version. Primed variables will indicate values at time $t + 1$.

The technology shock z and underlying asset of the option x have compact support, respectively, in $\mathcal{Z} = [z_l, z_u]$ and $\mathcal{X} = [x_l, x_u]$, with $S_h = \mathcal{Z} \times \mathcal{X}$, given my assumptions on the error terms ε_t^z and ε_t^x. $S_{cb} = \mathcal{Z}$ in the model with cash holdings. I assume capital and inventories take value, respectively, in $\mathcal{K} = [0, k_u]$ and $\mathcal{N} = [0, n_u]$ where k_u and n_u are uniquely determined given the concavity of the production function and linear depreciation costs. Capital and inventories values, respectively, outside $[0, k_u]$ and $[0, n_u]$ are not profitable and can be ignored without affecting my results.[14] h lies in $\mathcal{H} = [0, h_u]$ where the lower bound and h_u are defined according to the collateral constraint presented in the previous section. Finally, cb belongs to $\mathcal{C} = [0, cb_u]$ where cb_u is chosen large enough to encompass all the levels of cb that are economically valuable to the firm, given the assumption on r_{cb}.

In each time period a budget constraint must be satisfied. Specifically, in the version of the model with derivatives, since the uses of funds must equal the sources of funds, the cash flow is

$$cf(u, u', s) = f(k, n, z) + h(F - x) - h'P(x) - \eta_k(IK, \ell_k) - \eta_n(IN, \ell_n). \tag{2.3}$$

With cash holdings in place of hedging the cash flow function becomes

$$cf(u, u', s) = f(k, n, z) + (1 + r_{cb})cb - cb' - \eta_k(I^k, \ell_k) - \eta_n(I^n, \ell_n). \tag{2.4}$$

I indicate $A = U \times S$ the set where the cash flow function is defined for both versions of the model where U stands for either U_h or U_{cb} and S stands for either S_h or S_{cb}.

Corporate risk management, obtained by either inventories, derivatives hedging or cash holdings, limits incurring distress costs and external financing costs, as in Froot, Scharfstein, and Stein (1993). Fazzari, Hubbard, and Petersen (1988) identify three main costs associated

[14] In the Appendix I describe the method used to compute k_u and n_u.

with equity issuance: tax costs, adverse selection costs as in Myers and Majluf (1984), and flotation costs. I capture the three cost components in reduced form with the function $\Lambda(cf) = \left(\lambda_0 + \lambda_1 cf + \lambda_2 cf^2\right)$ where $\lambda_j > 0$ for $j = 0, 1, 2$ as in Hennessy and Whited (2005). Dividends are defined as $e(u, u', s) = cf(u, u', s) + \chi_{cf<0}\Lambda(cf(u, u', s))$.[15]

According to the *principle of optimality* (Bellman (1957)) I transform the program (SP) into the associated Bellman equation

$$v(u, s) \;=\; \max\left\{\left[\max_{u'\in\Gamma(u,s)} e(u, u', s) + \beta\int_{S'} v(u', s')\,\mu(s,\, ds')\right], 0\right\}, \tag{B}$$

where $v(u, s)$ is the value function corresponding to the value of firm's equity, $\Gamma(u, s)$ is the feasible set where controls take value and $\mu(s,\, ds')$ is the probability measure defined on the σ-algebra on S', conditional on state s_i. In the event of default the sum of internally generated funds from operations and futures payoff if positive and the funds raised from assets liquidated are used to partially repay operating fixed costs and possible obligations related to the futures contract. After default, a new firm starts business endowed with a random level of assets.

The following propositions, that can be easily extended to the version of the model with cash holdings, proved in the Appendix, identify the main characteristics of the value function $v(u, s)$ and of the optimal policy function in the model with hedging with derivatives.

Proposition 1. *The solution of the Bellman equation (B) exists, it is continuous and it coincides with the unique maximum attained solving the program (SP).*

Proposition 2. *The firm value function is monotonically increasing in k, n and h.*

Proposition 3. *The firm value function is concave and the optimal policy function is unique and continuous.*

2.3.1 Optimal Policies

In this section I provide an analytic explanation of the economic mechanisms governing the allocation of resources to capital, inventories and either futures or cash holding. I derive the the Euler equations with respect to the control variables. I take advantage of Theorem 9.10 in Stokey and Lucas (1989) by assuming that the value function is continuously differentiable in the three controls k', n' and h' for all $(z, x) \in S$. I assume also that the probability measure $\mu(s,\, ds')$ is non-atomic so that kink points related to indicator functions can be ignored in the derivation

[15] χ_A is the indicator function of event A.

of the Euler equations. In addition, assume evaluating optimal policies in states (u, s) for which real investments are nonzero, $k' \neq (1-\delta_k)k$ and $n' \neq (1-\delta_n)n$, and the firm neither distributes nor issues new equity, $e(u, u', s) \neq 0$. To simplify notation, I indicate with $\mathsf{i} = \{e(u, u', s) < 0\}$ the event of equity issuance, with $\mathsf{lc} = \{h(x-F) - f(k, n, z) > 0\}$ the event of asset liquidation due to obligation in the futures contract and with $\mathsf{lcn} = \{h(x-F) - f(k, n, z) > \ell_n(1-\delta_n)n\}$ the event of total liquidation of inventories to meet the obligations in the futures contract.

I derive the Euler equations for k and n for the version of the model with hedging. The corresponding optimality conditions for the model without financial hedging and the model with cash holdings are given by the same equations after deleting the parts related to liquidation costs related to hedging. The optimality condition for investment in capital stock is

$$\eta^k_{k'}(IK, \ell_k)\big[1 + \chi_{\mathsf{i}}\Lambda_{k'}(cf)\big] = \beta \int \Big\{ f_{k'}(k', n', z') + \eta^k_{k'}(IK', \ell_k)\big[1 - \delta_k + \ell_k^{-1}\chi_{\mathsf{lcn}} f_{k'}(k', n', z')\big] + \eta^n_{k'}(IN', \ell_n)\ell_n^{-1}\chi_{\mathsf{lc}}(1 - \chi_{\mathsf{lcn}}) f_{k'}(k', n', z') \Big\} \big[1 + \chi_{\mathsf{i}'}\Lambda_{k'}(cf')\big]\, \mu(s, ds'). \quad (2.5)$$

The marginal cost of investing in capital, in the left-hand side of equation (2.5), is given by the investment expense $\eta^k_{k'}(IK, \ell_k)$ augmented with contingent external finance costs proportional to the size of the investment because of the increased likelihood of incurring external financing costs due to the investment decision. The marginal cost of the investment becomes a marginal benefit if the firm decides to liquidate capital. At the same time, the marginal benefit of capital in the right-hand side of equation (2.5) is reduced. The present value of the marginal benefit of investing in capital can be decomposed in four parts. The first term between braces $f_{k'}(k', n', z')$ is the marginal productivity of capital. The second term $(1 - \delta_k)$ is the marginal value of depreciated capital stock. The third term $\ell_k^{-1}\chi_{\mathsf{lcn}} f_{k'}(k', n', z')$ is the marginal value of capital in terms of reduction of capital liquidation costs because of incremental cash flow from operations. Both the second and third terms are valued one or ℓ_k in relation to the investment decision for the next period. The fourth term $\eta^n_{k'}(IN', \ell_n)\ell_n^{-1}\chi_{\mathsf{lc}}(1 - \chi_{\mathsf{lcn}}) f_{k'}(k', n', z')$ is the reduction of inventories liquidation costs related to marginal cash flow generated by capital. These four terms together decrease the likelihood of incurring external financing costs. In the version of the model with no financial hedging and in the version with cash holdings the Euler equation for capital is simply given by

$$\eta^k_{k'}(IK, \ell_k)\big[1 + \chi_{\mathsf{i}}\Lambda_{k'}(cf)\big] = \beta \int \Big\{ f_{k'}(k', n', z') + \eta^k_{k'}(IK', \ell_k)(1 - \delta_k) \Big\} \big[1 + \chi_{\mathsf{i}'}\Lambda_{k'}(cf')\big]\, \mu(s, ds').$$

The optimality condition related to inventories is

$$\eta^n_{n'}(IN,\ell_n)\left[1+\chi_{\mathsf{i}}\Lambda_{n'}(cf)\right] = \beta\int\Big\{f_{n'}(k',n',z')+\eta^k_{n'}(IK',\ell_k)\ell_k^{-1}\chi_{\mathsf{lcn}}[f_{n'}(k',n',z')+\ell_n(1-\delta_n)]+ \\ \eta^n_{n'}(IN',\ell_n)\left[1-\delta_n+\ell_n^{-1}\chi_{\mathsf{lc}}(1-\chi_{\mathsf{lcn}})f_{n'}(k',n',z')-\chi_{\mathsf{lcn}}(1-\delta_n)\right]\Big\}\left[1+\chi_{\mathsf{i}'}\Lambda_{n'}(cf')\right]\mu(s,ds'), \tag{2.6}$$

where the investment expense, augmented with possible equity issuance costs, in the left-hand side of (2.6) equals the present value of marginal benefit of inventories investment in the right-hand side. Also in this case, if the firm decides to liquidate inventories it will get a lower marginal benefit in the future. The first component $f_{n'}(k',n',z')$ of the marginal benefit of inventories between braces is the operating convenience of inventories as a production factor. The convenience of holding inventories crucially depends on technology parameters like the elasticity of substitution parameter ν. The higher the complementarity between capital and inventories the higher the contribution to value of investing in inventories given the positive dependence of marginal productivity from ν. In addition, the state of z impacts the marginal productivity of inventories. For example, input supply shocks or production disruptions that impede the firm from satisfying product demand, are much more costly if demand is high as reflected by an high realization of z. Consequently, the avoidance of costly stockouts is particularly valuable when z is high implying a higher return from inventories.

The second component $\eta^k_{n'}(IK',\ell_k)\ell_k^{-1}\chi_{\mathsf{lcn}}[f_{n'}(k',n',z')+\ell_n(1-\delta_n)]$ is the reduction of capital liquidation costs because of additional operating cash flow generated by inventories and because of the possibility to use inventories as a buffer before liquidating capital. This component is valued at one or ℓ_k depending on the capital investment decision for the next period. The third term, $(1-\delta_n)$, is the marginal value of depreciated inventories stock. The fourth term of marginal revenue of inventories, $\ell_n^{-1}\chi_{\mathsf{lc}}(1-\chi_{\mathsf{lcn}})f_{n'}(k',n',z')$, is the reduction of inventories liquidation costs provided by incremental internal funds generated by inventories stock. The fifth component, $\chi_{\mathsf{lcn}}(1-\delta_n)$, is the marginal cost of holding inventories due to the priority in liquidation due to obligations in the futures contract. These last three components of the right-hand side of (2.6) are valued at one or ℓ_n according to the inventories investment decision for the next period. As in the case of capital, the marginal benefit provided by inventories, in the right-hand side of (2.6), besides directly contributing to firm value, decreases the likelihood of incurring external financing costs. This is the risk management benefit provided by inventories with respect to external finance costs. In summary, the contribution of inventories to firm value derives from substitution flexibility, embedded in inventories marginal productivity, and from its role as a reserve of liquidity. Simplifying notation with respect to expectation and discounting, the marginal contribution of inventories to firm value through the channel of substitution flexibility is

$$f_{n'}(k', n', z')[1 + \eta^k_{n'}(IK', \ell_k)\ell_k^{-1}\chi_{\mathsf{lcn}} + \eta^n_{n'}(IN', \ell_n)\ell_n^{-1}\chi_{\mathsf{lc}}(1 - \chi_{\mathsf{lcn}})],$$

and the contribution through the channel of liquidity is

$$(1 - \delta_n)[\eta^k_{n'}(IK', \ell_k)\ell_k^{-1}\chi_{\mathsf{lcn}}\ell_n + \eta^n_{n'}(IN', \ell_n) - (1 - \chi_{\mathsf{lcn}})].$$

In the versions of the model without financial hedging or with cash holdings, the benefits of inventories are simply given by $f_{n'}(k', n', z')$ and $\eta^n_{n'}(IN', \ell_n)(1 - \delta_n)$ and the Euler equation is

$$\eta^n_{n'}(IN, \ell_n)\big[1 + \chi_{\mathsf{i}}\Lambda_{n'}(cf)\big] = \beta \int \Big\{f_{n'}(k', n', z') + \eta^n_{n'}(IN', \ell_n)(1 - \delta_n)\Big\}\big[1 + \chi_{\mathsf{i}'}\Lambda_{n'}(cf')\big]\, \mu(s, ds').$$

The optimality condition related to the investment in futures is

$$\begin{aligned} &P(x)\big[1 + \chi_{\mathsf{i}}\Lambda_{h'}(cf)\big] = \\ &\beta \int (F - x')\Big\{1 + \eta^k_{h'}(IK', \ell_k)\ell_k^{-1}\chi_{\mathsf{lcn}} + \eta^n_{h'}(IN', \ell_n)\ell_n^{-1}\chi_{\mathsf{lc}}(1 - \chi_{\mathsf{lcn}})\Big\}\big[1 + \chi_{\mathsf{i}'}\Lambda_{h'}(cf')\big]\, \mu(s, ds'). \end{aligned} \tag{2.7}$$

The marginal cost of investing in the futures is given by the price of the futures and by the possible equity issuance costs due to the hegding decision. Conversely, when the price of the futures is negative, the firm receives additional funds by entering the futures. This decision implies a reduction of the likelihood of incurring external financing costs. In the right-hand side of (2.7), the present value of the marginal benefit of hedging with the futures is given by the payment $F - x'$ if positive. If $F - x' < 0$, it is an outflow for the firm and in the event internally generated funds are not enough to make the payment, assets must be liquidated. This implies two additional marginal costs related to hedging with futures given by the liquidation of inventories and capital, respectively, the second and the third terms between braces in the right-hand side of equation (2.7). These costs are higher when the firm pursues investments because they are valued at one which is the price paid for new capital and inventories. The benefits or costs provided by the futures in the right-hand side of (2.7) reduce or increase the likelihood of bearing future external financing costs. This fact highlights that real assets actually service obligations in the futures thereby providing a lower incentive to hedge.

The Euler equation related to cash is given by

$$\left[1 + \chi_{\mathrm{i}}\Lambda_{cb'}(cf)\right] = \beta \int (1 + r_{cb})\left[1 + \chi_{\mathrm{i}'}\Lambda_{cb'}(cf')\right] \mu(s, ds'), \tag{2.8}$$

where in the left-hand side I have the cost of holding cash increased by possible external equity costs due to saving instead of distributing cash. In the right hand side of equation (2.8) I have the marginal benefit of holding cash given by the interest income and the reduced likelihood of incurring external equity costs. The benefit provided by cash, in the right-hand side of (2.8), is given by savings augmented with earned interests plus the reduced likelihood of incurring external finance costs.

2.4 Numerical Results

In this section I numerically study the effect of the integrated management of inventories and hedging, implemented with either derivatives or cash holdings, on firm value using the model developed in previous sections. Given the properties of the value function, I solve (B) using a successive approximations method to find firm value and the optimal policies for capital, inventories and hedging. I discretize the capital set $\mathcal{K}$, and the inventories set $\mathcal{N}$ between zero and k_u and between zero and n_u respectively with points chosen as $k_u(1-\delta_k)^{j/4}$ and $n_u(1-\delta_n)^{j/4}$ with $j = 1, ..., 21$. The sets of h and cb are discretized respectively in $[0, h_u]$ and $[0, cb_u]$ with 21 equally-spaced points. The stochastic variables z and x define a reduced-form vector autoregression that I approximate through a discrete-state Markov chain with 9 points for each variable with truncated support in $[-3\sigma_j^u, 3\sigma_j^u]$, $j = x, z$, where $\sigma_j^u = \sigma_j/\sqrt{1-\rho_j^2}$ is the unconditional standard deviation for $j = x, z$. The discrete abscissae and the risk neutral Markov transition probabilities are computed according to Terry and Knotek (2011) extension of Tauchen (1986) method, which is based on Gauss-Hermite quadrature rule but allowing for nonzero correlation.

2.4.1 Calibration

I calibrate my model in annual frequency. The autoregressive coefficient of z, ϕ_z, is set to 0.62 and σ_z to 0.15 according to Gomes (2001). The autoregression ϕ_x and the volatility σ_x are also set, respectively, to zero, 0.62 and 0.15 in order to have a marginal distribution of x comparable to that of z. The correlation parameter ranges between 0 and 1 and I set it to 0.1 for the base case. However, I will show results also for other values of of ρ.

As I adopt the same technology specification as in Belo and Lin (2012), I select the technology parameters accordingly except for the return to scale parameter, θ, that I conservatively set to 0.45, instead of 0.7 as in Belo and Lin (2012), not to overstate the return from inventories investment. Moreover, my choice is in the range of values used in literature. For example, estimates in Basu and Fernald (1997), Burnside, Eichenbaum, and Rebelo (1995) and Basu, Fernald, and Shapiro (2001) are very close to constant returns to scale. Jones and Tuzel (2013) set the returns to scale respectively to 0.30 but they use also depreciation rates for capital and inventories lower than mine. I set the parameter measuring the relative contribution of capital to output $\alpha = 0.78$ and the elasticity of substitution parameter $\nu = 0.5$ as in Belo and Lin (2012). For comparison, Kydland and Prescott (1982) and Christiano (1988) estimate a complementarity parameter respectively equal to 4 and to 3.6. However, both studies use a different production function comprising labor and focus on the U.S. economy in the post-war period until the beginning of the 80's. In contrast, recent asset pricing contributions focus on a wider time span from the post-war period to 2009-2010 and set the complementarity parameter between 0.5 and 2. For example, Belo and Lin (2012) estimate $\nu = 0.5$ by matching the simulated inventories-to-sales ratio with the empirical counterpart of 17% in a sample of U.S. firms between 1965 and 2009. In a sample of U.S. firms between 1958 and 2010, Jones and Tuzel (2013) calibrate parameters in their model with values ν ranging between zero and 2 and using $\nu = 1$ as their base case value. For these reasons I will present a sensitivity analysis of my results on ν. Capital depreciation rate δ_k is set to 0.12, in agreement with Kydland and Prescott (1982), Gomes (2001), Hennessy and Whited (2005) and Cooper and Haltiwanger (2006). Consistently with Belo and Lin (2012), the inventories depreciation rate δ_n is set to 0.24 which is in the range 0.19-0.43 reported by Richardson (1995) and approximately equal to 0.25 reported in Ramey (1989). For comparison purposes, Jones and Tuzel (2013) adopt a quarterly 0.05 depreciation rate, which corresponds to an annual 0.2. I set fixed operating costs to 0.65 which is in the range 0.45-1.35 adopted in Moyen (2004). I set $\ell_k = 0.85$ and $\ell_n = 0.93$ to match corresponding values in Belo and Lin (2012) who adopt an asymmetric investment cost function with fixed and convex components. The forward price F for the futures contract is set to 1, which is also the unconditional average value of the price of the underlying asset. The equity issuance cost parameters λ_0, λ_1 and λ_2, are set, respectively to 0.389, 0.053 and 0.0002 which are the lowest values estimated for large COMPUSTAT firms by Hennessy and Whited (2007). my choice of λ_1 is also not far from estimates in Hennessy and Whited (2005) of 0.059 and in Altinkilic and Hansen (2000) of 0.0515. I set the discount factor at $\beta = 1/1.05$

and the interest rate on cash holding r_{cb} to 0.045. All parameters values are summarized in Table 2.1.

Parameter	*Symbol*	*Value*
Returns to scale	θ	0.45
Capital contribute to output	α	0.78
Elasticity of substitution parameter	ν	0.5
Capital depreciation rate	δ_k	0.12
inventories depreciation rate	δ_n	0.24
Capital liquidation price	ℓ_k	0.85
inventories liquidation price	ℓ_n	0.93
Fixed operating costs	fc	0.65
Autoregression of z_t	ϕ_z	0.62
Volatility of z_t	σ_z	0.15
Autoregression of x_t	ϕ_x	0.62
Volatility of x_t	σ_x	0.15
Correlation	ρ	0.1
Forward price	F	1
	λ_0	0.389
Equity issuance costs	λ_1	0.053
	λ_2	0.0002
Discount factor	β	1/1.05
Cash holdings return	r_{cb}	0.045

Table 2.1. Base Case Parameters.

2.4.2 The Contributions of Inventories and Derivatives to Firm Value

One of the challenges of this work is to disentangle the role of inventories as a production factor from its role as a risk management tool. Then, in what follows I select as the benchmark the model in which capital can be controlled, inventories are constant at the unconditional average and no hedging is performed. In addition, the choice of this benchmark model is dictated also by the fact that I are studying firms that use inventories as a factor of production so it is not correct to exclude inventories from the production function. In such a case I would deal with a completely different technology which is not comparable with the technology specification I adopt. In this way, I can compute the risk management contribution of inventories to firm value holding constant its contribution as a production factor. Against this benchmark, I compute the relative contribution to risk management of inventories, derivatives and cash holdings. I will add to the benchmark model these controls in order to assess their individual and joint contribution to the value of risk management. I label "Inventories" the model in which inventories can be managed bu the firm has no access to derivatives; "Derivative" the model in which the firm uses futures, while inventories is kept constant at the steady state level; "Inventories & Derivative" the model where the firm controls capital, inventories and hedging.

Unconditional averages of endogenous variables are computed with simulation of the "inventories & Derivative" model with 10000 paths and 200 time periods from which I deleted the first 50 observations for each path in order to exclude for any influence of the initial conditions of the simulations. I control for the fact that the unconditional average of inventories can be different among variations of the model. However, from my simulations it turns out that such difference among unconditional averages of inventories is negligible so that the results are not influenced by the choice of unconditional average inventories.

In Figure 2.1and Figure 2.2 I plot firm value as function of variables. In Figure 2.1 firm value is shown as a function of capital stock k and inventories stock n. Firm value is increasing and concave in both variables meaning that marginal value that managers can add by increasing assets stocks is bounded. The concavity of the firm value with respect to inventories stock derives from decreasing return to scale of inventories. Pindyck (1994) adopts a different modeling approach by specifying a cost function convex in the stock of inventories. In his model drawing down inventories is very costly. This cost is progressively reduced as the firm increases the stock of inventories. The cost of not having inventories are given by stockout costs. In this work I follow the neoclassic modeling approach by specifying a production function but the economic mechanism is the same as in Pindyck's model.

In Figure 2.2 I plot firm value as a function of the notional of the futures h and the underlying assets x. The payoff of the futures for the firm is linear as long as liquidation costs do not come into play. The firm is more likely to liquidate asset to meet obligations in the futures when x is in the right-tail of the distribution. In this event the firm not only needs to pay the counterpart in the futures but it also bear liquidation costs if internally generated funds from operations are not enough to make the payment. The effect of liquidation costs can be seen observing in Figure 2.2 firm value that is concave in x. Obviously, liquidation costs are heavier if the firm allocate more resources to hedging for high values of h.

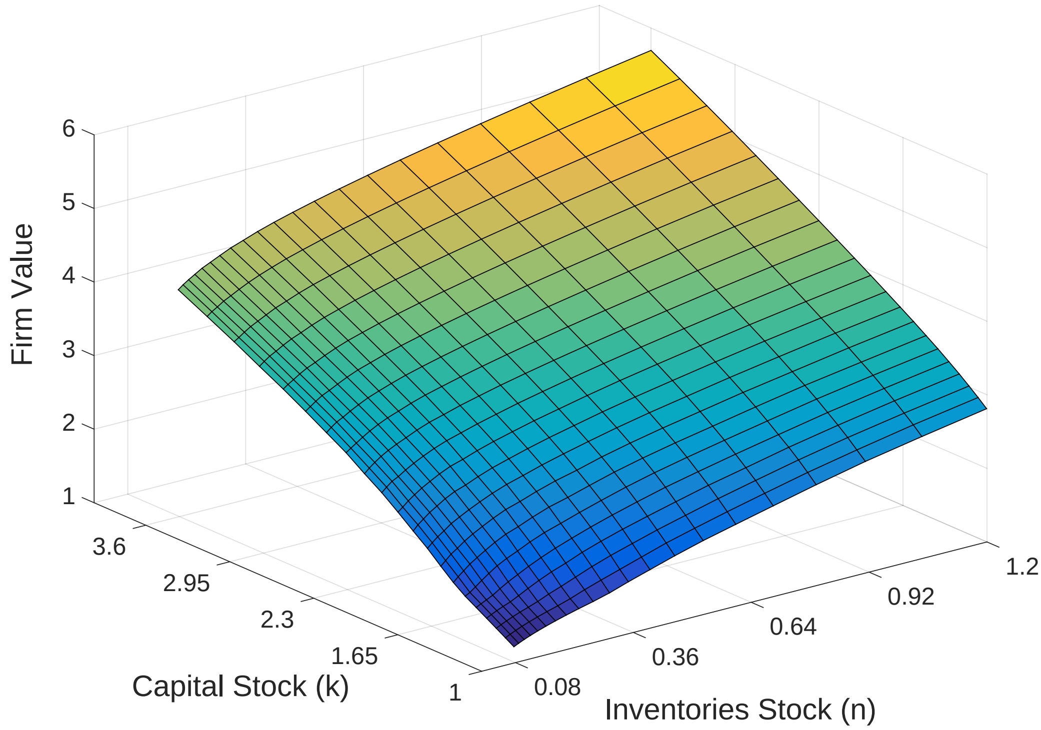


Figure 2.1. Firm Value as a Function of Capital and Inventories. In this figure I plot firm value as function of capital stock k and inventories stock n. Firm value is shown for the average values of the shock $z = 1$ and the underlying asset of the futures $x = 1$ under base case parameters.

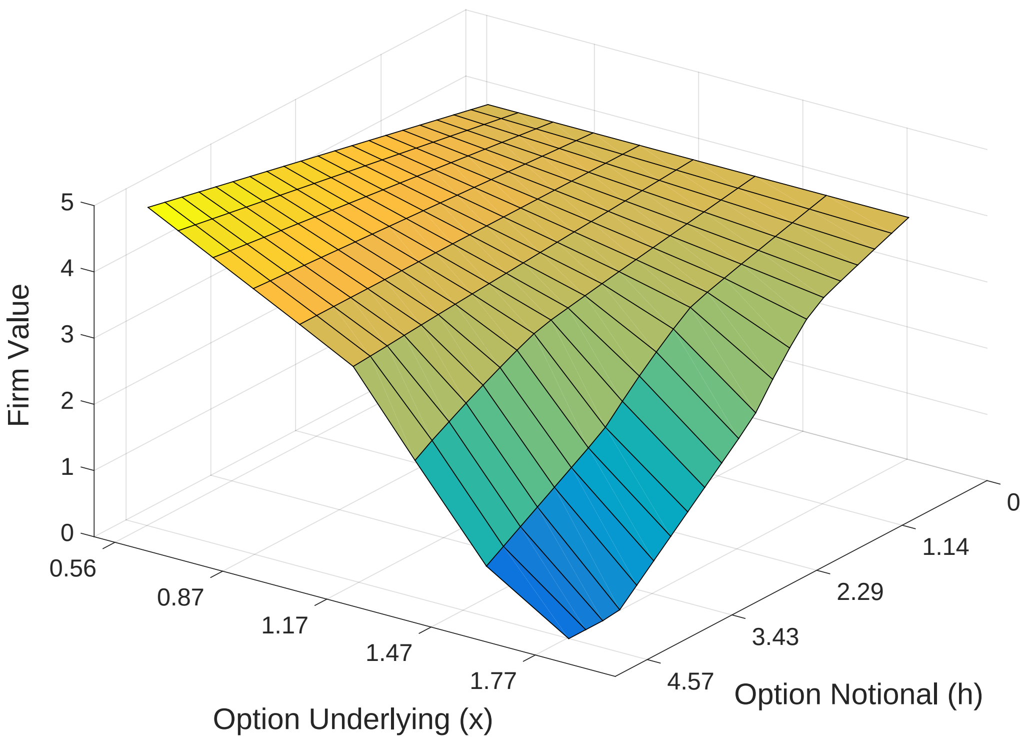


Figure 2.2. Firm Value as a Function of Notional and the Underlying Asset of the Futures. In this figure I plot firm value as function of notional h and the underlying asset x of the futures. Firm value is shown for the average values of capital stock $k = 2.24$ and inventories stock $n = 0.68$ under base case parameters.

In the literature, while the relative higher liquidity of inventories has been widely documented, the complementarity between inventories and capital has not been investigated from a financial point of view. In Figure 2.3, I show the percentage value increase in the "inventories" case for different values of the complementarity parameter ν against the base case level of 0.5. As expected, increasing complementarity (higher ν) negatively impacts the risk management value of inventories. When capital and inventories are complement, inventories cannot substitute for capital, for example, in the event of a production disruption, which entails losing sales that leads to a lower cash flow. Furthermore, for high complementarity the firm must hold a quantity of all production factors essential to the production process. This generates an implicit cost related to the lower return from inventories influenced by $(1-\alpha)$ and depreciation δ_n. Even if the substitutability value of inventories increases with lower ν this is not enough to compensate this loss of return with respect to capital. As it is shown in Figure 2.3, increasing the degree of complementarity from 0.5 to 0.75, firm value decreases on average by about 10% (being twice as bigger for $\nu = 1$). On the other hand, reducing complementarity from $\nu = 0.5$ to $\nu = 0.25$ leads to an average value increase of about 14% (and about 32% for $\nu = 0.01$). Although firm value increases with lower complementarity between assets, the relative contribution of inventories however becomes smaller as it can be seen in Figure 2.4, where I plot the percentage value increase due to adding inventories management to the benchmark model (without the dynamic management of inventories) including the base case value of 0.5. As reported in Table 2.2, for $\nu = 0.25$ the value increase is on average 2.27% which increases to 4.53% for $\nu = 0.5$ and to 5.68% for $\nu = 0.75$. As complementarity increases, although firm value is overall lower, the value contribution of inventories becomes larger because it provides unique services in the production process. On the other hand, if the firm for a given level of production can easily substitute factors of production it will be convenient to invest in more remunerative factors like capital. In summary, I detect two channels through which lower complementarity affects firm value: first, it increases firm value due to higher flexibility between the two production factors; second, a substitution effect in the optimal mix of production factors penalizes assets with lower returns. This effect can be seen observing Table 2.3 where I report descriptive statistics of inventories ratio ($n/(k+n)$), hedge ratio ($h/(g(k,n,z)/z)$) and hedge-to-assets ratio ($h/(k+n)$) computed in the "Inventories & Derivative" case. Hedge ratio equals the notional amount in the futures scaled by production, say, the production function divided by z assuming that z subsumes the price of the output. This hedging measure is adopted, among others, in Tufano (1996) and Jin and Jorion (2006) where the hedge ratio is defined as the derivatives portfolio's delta multiplied by the derivatives portfolio's notional scaled by production. In my case the derivative's delta is one since I only consider a futures. The average inventories ratio increases with complementarity, from 19.3% with $\nu = 0.25$, to 23.2% with $\nu = 0.5$ and to 26% with $\nu = 0.75$.

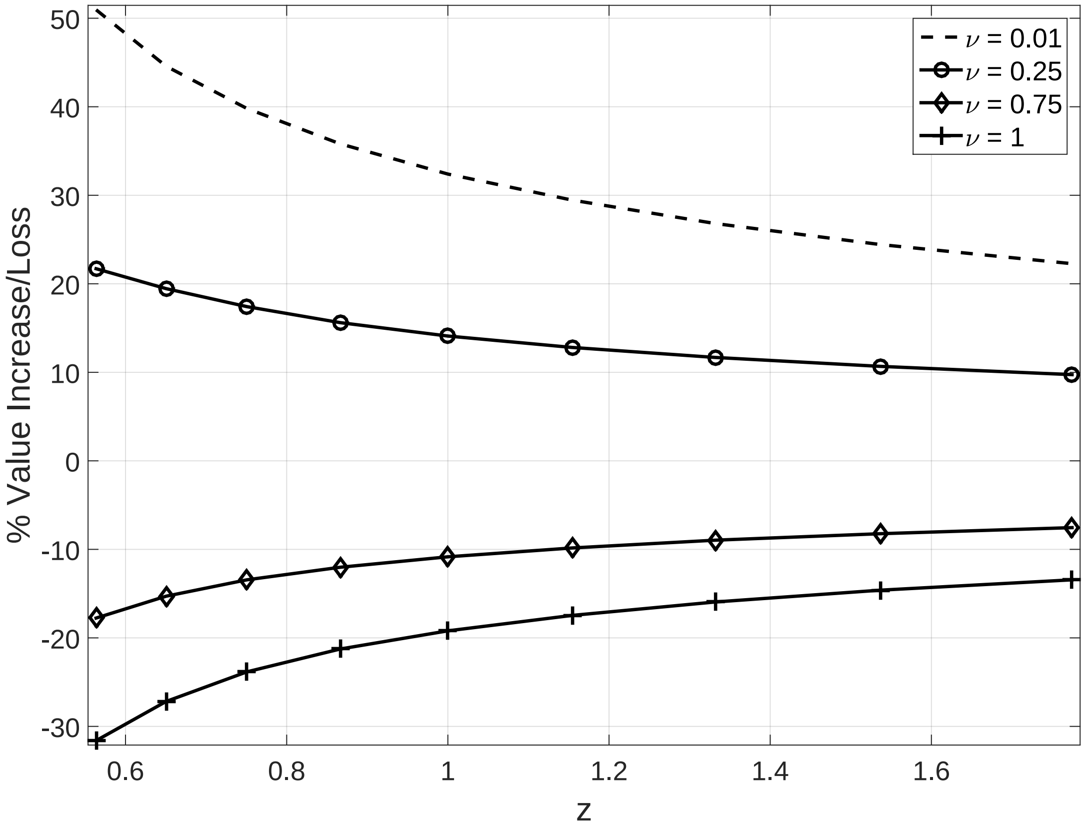


Figure 2.3. The Effect of Complementarity between Capital and Inventories on Firm Value. For the "Inventories" case I depict as a function of z the percentage difference in firm value due to different levels of complementarity between capital and inventories, ν, with respect to the base case with $\nu = 0.5$. Firm value is shown for the average levels of the variables computed simulating optimal policies in the base case with $\nu = 0.5$, which are 2.24 for capital and 0.68 for inventories.

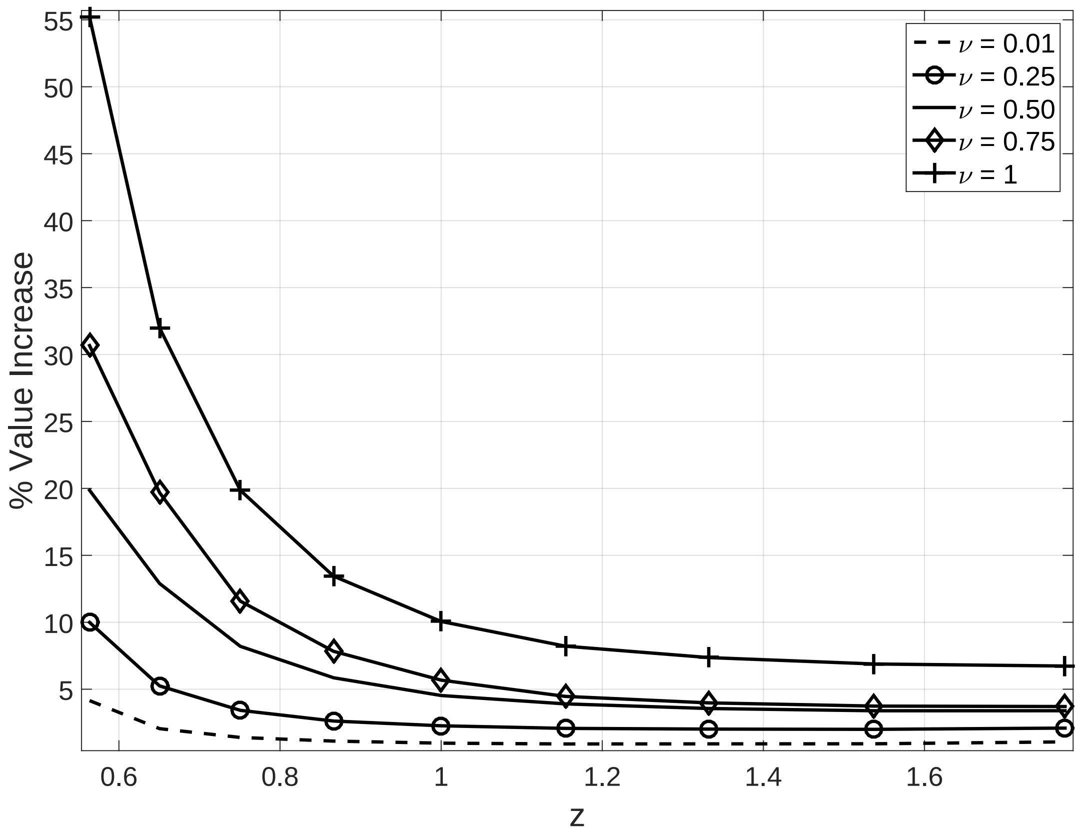


Figure 2.4. **The Effect of Complementarity on the Contribution of Inventories to Firm Value**. In this figure, I show, against the shock z, the firm value percentage increase due to adding inventories management to the benchmark model. I show firm value increase in five different scenarios identified by the complementarity parameter ν. Firm value is shown for average levels of k and n in each case, which are, respectively, 2.77 and 0.46 for $\nu = 0.01$, 2.45 and 0.58 for $\nu = 0.25$, 2.24 and 0.68 for $\nu = 0.5$, 2.06 and 0.72 for $\nu = 0.75$, 1.89 and 0.75 for $\nu = 1$.

The second channel through which inventories contribute to firm value refers to their role as a reserve of liquidity. The relevant metric in this case is the ratio ℓ_n/ℓ_k, which summarize the degree of liquidity of assets in a relative manner. I compute the contribution to firm value of inventories by only varying ℓ_k below the base case value of 0.85. In Figure 2.5 I graphically expose results. The average value increase is 4.53% under base case value $\ell_k = 0.85$, 5.42% with $\ell_k = 0.50$ and 6.22% with $\ell_k = 0.15$. These results suggest that inventories play a significant role in mitigating the impact of capital illiquidity. However, the value increase due to inventories management derives from both the operating flexibility and its role as a liquidity reserve. To isolate these components, I compute the marginal contribution of inventories management under the same values of ℓ_k previously used but with $\ell_n = 0$. In this case, inventories are fully irreversible and cannot be used as a reserve of liquidity. I find average value increases of 4.51%, 5.32% and 5.98%, respectively, for ℓ_k equal to 0.85, 0.50 and 0.15. Given the negligible difference between the base case $\ell_n = 0.93$ and $\ell_n = 0$, these results indicate that most of the contribution of inventories management to firm value derives from operating substitution flexibility. Conversely, the component of value that can be attributed to inventories as a reserve of liquidity is quite small.

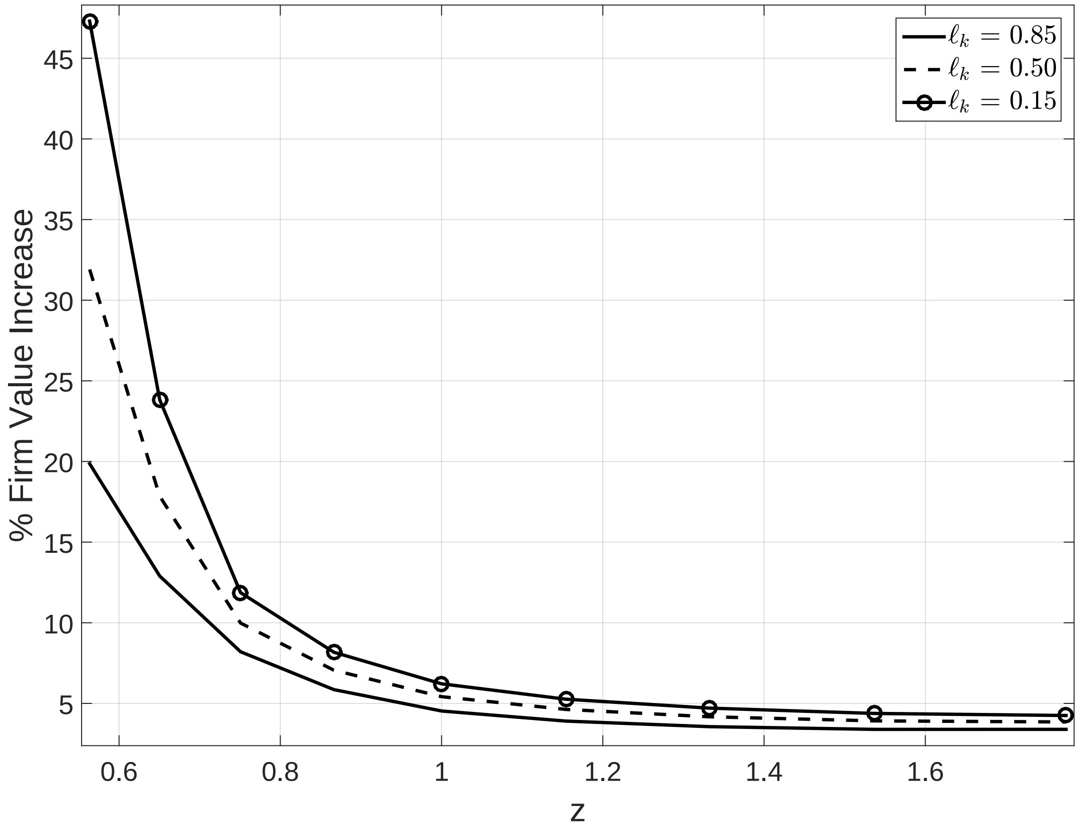


Figure 2.5. The Effect of Liquidity on the Contribution of Inventories to Firm Value. In this figure, I show, against the shock z, the firm value percentage increase due to adding inventories management to the benchmark model. I show firm value increase for ℓ_k equal to 0.85 (base case), 0.50 and 0.15. Firm value is shown for average levels of k and n, respectively, 2.24 and 0.68 in three scenarios considered.

Having studied the effect of production complementarity and liquidity, the two channels through which inventories management influence firm value, I can move to the study of the interaction between inventories and hedging. In Figure 2.6 I show the percentage value increases due to the addition of the management of inventories and hedging with the futures to the benchmark model under base case parameters. The numerical value of average percentage value increases is reported in Table 2.2 for the base case and a selection of other cases. I observe that inventories and hedging contributions to firm value are progressively less important as the state of the firm's business improves, as intuitively marginal benefits of risk management decrease with the state of the business. Secondly, I observe that, on average, inventories contributes to firm value slightly more than hedging. Under base case parameters, the contribution of inventories to value equal to 4.53% while the percentage value increase due to hedging with futures averages 2.42% as shown in the case "Derivative". Once added the dynamic management of inventories, the incremental contribution of the futures, computed as the difference between the value increases in the "Inventories & Derivative" case and the "Inventories" case, approximately averages 0.77% given a joint contribution of inventories and hedging with futures equal to 5.30% in the "Inventories & Derivative" case.

In the third column of Table 2.2, I report the contributions of inventories and hedging to firm value with $\nu = 0.75$, whereby capital and inventories have a higher complementarity. The marginal value contribution of inventories and hedging with futures are, respectively 5.68% and 3.86% on average. Inventories management and hedging become especially valuable given the reduced flexibility due to higher complementarity. The joint contribution of inventories and hedging to firm value averages 6.86% with the incremental contribution due to the management of the futures equal only to 1.18% leaving again most of the firm value increase attributable to inventories management. In Table 2.3, the inventories ratio increases with higher complementarity reflecting the higher need of inventories when capital cannot substitute for it. The resources devoted to hedging also increase, leading to an increase in the hedge ratio from 20.7% with $\nu = 0.5$ to 23.4% with $\nu = 0.75$.

	1	2	3	4	5	6	7	8	9
Variable	*Base Case*	$\nu = 0.25$	$\nu = 0.75$	$fc = 0.6$	$fc = 0.7$	$\rho = 0.5$	$\rho = 1$	$\sigma_z = 0.10$	$\sigma_z = 0.20$
Inventories	4.530	2.269	5.679	2.159	10.445	4.530	4.530	0.117	5.119
Derivative	2.421	0.964	3.860	0.746	3.744	3.869	6.944	1.157	1.123
inventories & Derivative	5.298	2.925	6.858	2.719	11.985	6.366	8.697	0.870	5.131

Table 2.2. The Marginal Contributions of Inventories and Derivatives to Firm Value. In this table I report the average percentage firm value increases due inventories management, "inventories", hedging, "Derivative", and controlling inventories and hedging, "Inventories & Derivative", in addition to capital. The percentage value increases are reported for the average value of the shock $z = 1$, for the value of $x = 0.866$ for which the futures most frequently pays to the firm and for the values of endogenous variables in the respective sets closest to unconditional averages of capital, inventories and notional in each parameter setting.

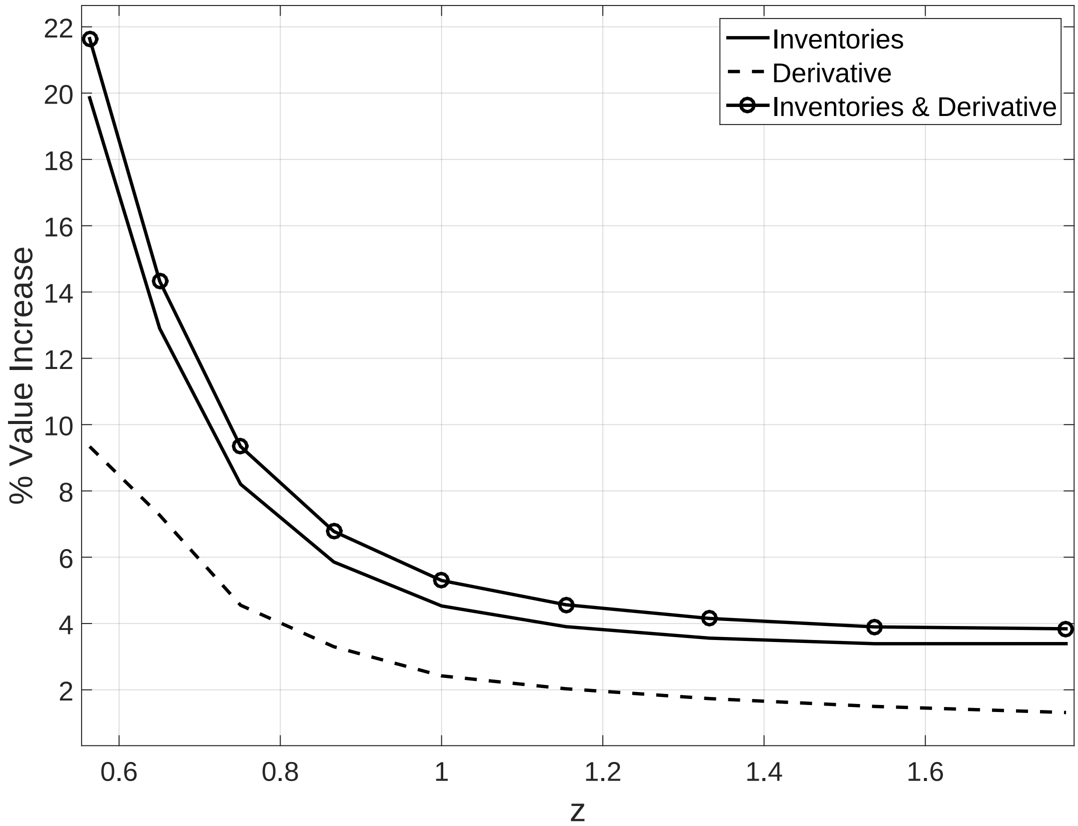


Figure 2.6. The Contributions of Inventories and Derivatives to Firm Value. In this figure, I show, against the shock z, the average percentage firm value increases of inventories, "Inventories" case, hedging with the futures, "Derivative", and the joint contribution of these controls, "Inventories & Derivative" case, with respect to the benchmark model in which only capital can be controlled. Percentage value increases are shown under base case parameters and for the unconditional average values of k, n and h, respectively, 2.26, 0.68 and 0.25, computed with simulation of "Inventories & Derivative" model and for the most frequent value of $x = 0.866$ for which the futures pays to the firm, say, the value right below the long term mean in the grid of x.

	Variable	Mean	Median	St.Dev.
Base case	Inventories Ratio	0.232	0.232	0.014
	Hedge Ratio	0.207	0.117	0.255
	Hedge/Assets	0.089	0.048	0.112
$\nu = 0.25$	Inventories Ratio	0.193	0.198	0.011
	Hedge Ratio	0.207	0.127	0.266
	Hedge/Assets	0.088	0.048	0.114
$\nu = 0.75$	Inventories Ratio	0.260	0.257	0.016
	Hedge Ratio	0.234	0.117	0.281
	Hedge/Assets	0.104	0.048	0.127
$fc = 0.6$	Inventories Ratio	0.236	0.243	0.012
	Hedge Ratio	0.216	0.127	0.246
	Hedge/Assets	0.094	0.048	0.109
$fc = 0.7$	Inventories Ratio	0.225	0.232	0.037
	Hedge Ratio	0.209	0.114	0.284
	Hedge/Assets	0.093	0.048	0.140
$\rho = 0.5$	Inventories Ratio	0.231	0.232	0.013
	Hedge Ratio	0.446	0.378	0.383
	Hedge/Assets	0.196	0.143	0.173
$\rho = 1$	Inventories Ratio	0.236	0.241	0.011
	Hedge Ratio	0.774	0.637	0.505
	Hedge/Assets	0.341	0.286	0.239
$\sigma_z = 0.1$	Inventories Ratio	0.229	0.230	0.010
	Hedge Ratio	0.222	0.118	0.298
	Hedge/Assets	0.085	0.048	0.108
$\sigma_z = 0.2$	Inventories Ratio	0.231	0.232	0.015
	Hedge Ratio	0.774	0.637	0.505
	Hedge/Assets	0.094	0.048	0.128

Table 2.3. Descriptive Statistics of the Model with Capital, Inventories and Hedging with Derivatives. In this table I report, under various parameters settings, the descriptive statistics of inventories ratio $n/(k+n)$, hedge ratio of production $h/(g(k,n,z)/z)$, and hedge/assets ratio $h/(k+n)$, for the "Inventories & Derivative" model. Unconditional moments are estimated from a panel of 10000 firms for 150 periods simulated using the optimal policy functions.

Inventories and hedging with derivatives importantly affect the firm's cash flow in the presence of significant operating leverage. Ramey (1989) explains that the benefit provided by inventories in terms of avoidance of input supply and production disruptions is valuable also because other factors of production can be continuously employed when such events occur. For example, here fixed operating cost may comprise fixed payments to labor which must be met in any state of the business. If inventories is available, workers can continue to work in production in the event of a supply shock and in sales in the event of a production disruption. Continuity in production and sales sustain cash flow so that fixed operating costs becomes less binding. This benefit from inventories derives from substitution flexibility that becomes very valuable when the operating cash flow is close to the level of fixed costs. Then, in that case having inventories sustain cash flow above fixed costs. Also inventories liquidity impacts positively the value of firms because in bad states of the business, if operating leverage binds, additional funds can be raised liquidating inventories, therefore avoiding external finance costs.

To gauge the impact of risk management tools for different levels of operating leverage, in columns four and five of Table 2.2, I report firm value increase in the "Inventories", "Derivative" and "Inventories & Derivative" cases with fixed costs set respectively to 0.6 and to 0.75, around the base case value of 0.65. First of all, I observe that the value increase is smaller in all cases cases when the operating leverage is set to 0.6. In the "Inventories" case the value increase is 2.16% while in the "Derivative" case it is 0.75%. In contrast, if operating leverage is 0.7 the marginal contribution of inventories dramatically increases to 10.45% lending support to Ramey (1989) arguments. The value increase in the "Derivative" case is also higher, averaging 3.74%, with higher operating leverage. Secondly, inventories still dominates futures for different levels of the operating fixed costs but the marginal contribution of inventories for $fc = 0.7$ is by far greater than that of the futures.

The correlation between the technology shock z and the futures underlying asset x crucially influences the performance of hedging with derivatives. In columns 6 and 7 of Table 2.2, I report the average contributions to firm value of inventories and hedging with the futures with $\rho = 0.5$ and $\rho = 1$. Firstly, I note that the contribution of hedging is greatly enhanced by correlation set higher than the base case level 0.1 because of the increased effectiveness of hedging cash flow. The value increase in the "Derivative" case averages 3.87% with $\rho = 0.5$ and 6.94% with $\rho = 1$. This result is in agreement with the findings in Gamba and Triantis (2014) where derivatives' contribution to value is in general very low except for the cases in which there is perfect conditional correlation between the cash flow and the underlying asset of the derivative contract.

Inventories becomes incrementally less valuable with higher ρ if the firm implements hedging with derivatives. The joint contribution of inventories and hedging to value averages 6.37% with $\rho = 0.5$ and 8.70% with $\rho = 1$ and for $\rho = 1$ derivatives account for the most part of the value gain that can be attributed to risk management leaving a 1.76% incremental value increase due to inventories management. In Table 2.3, I observe that the hedge ratio are higher with higher values of correlation. For example, the hedge ratio equals on average 44.6% with $\rho = 0.5$ and 77.4% with $\rho = 1$, much higher than 20.7% with $\rho = 0.1$ (base case).

I find that increasing the technology shock volatility leads the firms to invest more in inventories and to hedge more with the futures. High volatility notoriously enhances the performance of reversible investments. In agreement, I find that the marginal contribution to firm value in the "Inventories" case averages 5.12% with $\sigma_z = 0.20$ compared to 4.53% under the base case level $\sigma_z = 0.15$, as reported in Table 2.2. In Table 2.3 I observe that the hedge ratio increases with σ_z set to 0.2. However, the contribution to firm value of hedging with futures reduces to 1.12%. This results derives from the fact the firm invest more in real assets when volatilty of the technology shock is high because both inventories and capital are reversible. This explains the slight change of the hedge to assets ratio between the base case with $\sigma_z = 0.15$ and the case with $\sigma_z = 0.20$. So, even if hedging is more valuable when z is very volatile its marginal contribution gets reduced because real assets (mainly inventories) become even more valuable.

Contrasting my results with previous studies on the contribution of hedging with derivatives to firm value, my findings are in general consistent with the risk management literature. Allayannis and Weston (2001) find on average a 5% increase in firm's Tobin's Q for U.S. non-financial firms adopting risk management policies on currency risk in years from 1990 to 1995. Carter, Rogers, and Simkins (2006) provide a range of 5% to 10% market-to-book increase for firms hedging fuel risk in their sample of U.S. airline companies. Pérez-González and Yun (2013) report an average increase in market-to-book ratio of 6%-8% statistically significant only for U.S. energy utilities between 1960 and 2007 with a very high exposure to weather risk.

As for hedge ratios, in Table 2.3, I observe an hedge ratio of 20.7% (11.7%) on average (median) under base case parameters, of 44.6% (37.8%) on average (median) with $\rho = 0.5$ and of 77.4% (63.7%) on average (median) with $\rho = 1$. The average (median) hedge ratio increases to 77.4% (63.7%) with $\sigma_z = 0.2$ greater than the 0.15 value in the base case. Hedge ratios are computed in variety of ways in the literature so my measure of hedging activity is directly comparable with some studies but it is different from other measures of hedging activity adopted in others. For example, Tufano (1998) measures hedging activity with the ratio of derivatives portfolio's delta over production for a sample of U.S. firms in the gold mining sector. He finds an average hedge ratio of 27%. Guay and Kothari (2003) adopt the ratio of derivatives' portoflio cash flow sensitivity to operating cash flow finding a median 10% in their sample. Carter, Rogers, and Simkins (2006) in their sample of U.S. airlines between 1992 and 2003 find that firms hedge on average 15% of their expense in jet fuel. Rampini, Sufi, and Viswanathan (2014) report similar results for the same industry finding that U.S. airlines in their sample hedged on average less than 25% of their fuel expense in the period 1996-2009. Finally, Jin and Jorion (2006) report an average of 33% for the ratio of derivatives' portfolio's delta scaled by production for U.S. oil and gas producers in the years between 1998 and 2001. my results are broadly consistent with findings in other studies given the differences in measuring hedging activity and the heterogeneity in hedging policies across firms and industries.

In the spirit of traditional empirical tests in the risk management literature, I estimate, with data obtained through simulation of the model, the following regression

$$r_{it} = \gamma_0 + \gamma_1 \, rz_{it} + \varepsilon_{it},$$

where r_{it} are stock returns and rz_{it} are returns of z for firm i at time t and ε_{it} are i.i.d. errors by definition orthogonal to rz_{it}. This exercise allows us to understand that the source of value increase previously discussed actually derives from additional flexibility provided by inventories and hedging with derivatives. This flexibility translates into a lower sensitivity of firm's stock returns to the technology shock z that moves the operating cash flow. In Table 2.4 I report the estimate of γ_1 in each of the versions of the model and for different parameter settings. As expected γ_1 is always high, between 0.833 and 0.909, in the "Benchmark" model. Secondly, adding either inventories or hedging with futures, I observe a decrease of γ_1 due to additional flexibility that neutralizes part of the the effects of z on stock returns. In agreement with my previous findings on the contribution of inventories to firm value, I find that the dynamic management of inventories reduces the sensitivity of stock returns to returns of z. More specifically, γ_1 reduces to 0.778 in the "Inventories" case. This effect is stronger as σ_z increases. In Column 5 of Table 2.4, I report γ_1 equal to 0.746. In agreement with Tufano (1998), hedging reduces the sensitivity of stock returns to cash flow shocks even more for flexible firms with very volatile cash flows. The value of flexibility is in fact enhanced by higher volatility.

I observe a reduction of γ_1 also when the firm implements hedging with futures especially when ρ is high. This is not surprising since the firm has more chances to effectively hedge cash flow when the technology shock is perfectly correlated with the underlying asset in the futures contract. Also in the "Derivative" case I observe a reduction of γ_1 with higher volatility even if this effect is less pronounced than in the "Inventories" case. γ_1 is minimized in the "Inventories & Derivative" case for all parameters settings with the exception of the case with $\rho = 1$ where the futures alone reduces γ_1 even more than jointly with inventories.

	1	2	3	4	5
Variable	$Base\,Case$	$\rho = 0.5$	$\rho = 1$	$\sigma_z = 0.1$	$\sigma_z = 0.2$
Benchmark	0.909	0.909	0.909	0.875	0.833
Inventories	0.778	0.778	0.778	0.800	0.746
Derivative	0.841	0.718	0.337	0.840	0.826
Inventories & Derivative	0.768	0.684	0.452	0.772	0.755

Table 2.4. **Stock Returns Sensitivities**. In this table I report the estimates of the parameter γ_1 in the regression of firm's stock returns on the returns of the technology shocks z, $r_{it} = \gamma_0 + \gamma_1 r z_{it} + \varepsilon_{it}$. Returns are computed on a panel of 10000 firms for 150 periods simulated with optimal policy functions computed in the "Benchmark", "Inventories", "Derivative" and "Inventories & Derivative" versions of the model. All estimates are statistically significant.

I study the sign of the relation between the investment in inventories and hedging in my model by estimating the following regression

$$hedge\,ratio_{it} = \mu_0 + \mu_1\, inventories\,ratio_{it} + \mu_2\, net\,worth\,ratio_{it-1} + \omega_{it},$$

where $hedge\,ratio_{it} = h_{it}/(g(k_{it}, n_{it}, z_{it})/z_{it})$, $inventories\,ratio_{it} = n_{it}/(k_{it} + n_{it})$, and

$$net\,worth\,ratio_{it} = [f(k_{it}, n_{it}, z_{it}) + h_{it}(F - x_{it}) + \ell_n(1-\delta_n)n_{it} - liq^n_{it} + \ell_k(1-\delta_k)k_{it} - liq^k_{it}]/(k_{it} + n_{it}),$$

where liq^j are contingent liquidation costs due to obligations in the futures, and ω_{it} are i.id. shocks orthogonal to regressors. The estimates of coefficients μ_j for $j = 0, 1, 2$ are reported in Table 2.5. Firstly, I find, in agreement with Rampini and Viswanathan (2010) and Rampini, Sufi, and Viswanathan (2014), a positive relation between net worth and hedging. Secondly, and more importantly for this study, I find a strong negative relation between hedging with inventories and hedging with the futures in all parameters settings. The only exception is the case with $\sigma_z = 0.1$. This result suggests that inventories and financial hedging are substitutes even after controlling for net worth which is the budget available to the firm. In unreported regressions, I estimated the same equation above replacing inventories ratio with the lags of inventories growth and the capital growth ratios finding a negative coefficient for the former and positive for the latter variable. Since inventories ratio summarizes the real investment decisions taken in period $t-1$ together with hedging decision, I decided to estimate regressions with only inventories ratio in addition to net worth ratio. I observe that the negative relation between inventories ratio and hedge ratio is stronger with higher operating leverage and higher correlation ρ. Higher fixed costs stimulate investment in inventories at the expenses of hedging with futures. On the other hand, hedging with futures absorbs more resources when the correlation between z and x is higher.

Observing the results from my model, I provide further evidence on the substitution effect between real flexibility and financial flexibility documented in other studies. For example, Mauer and Triantis (1994) and MacKay (2003) provide, respectively, theoretical and empirical evidence on the negative relation between real flexibility, mainly in the form of production volume flexibility, and financial flexibility in the form of flexible debt financing. Restricting the scope to studies that explicitly compare various hedging strategies, Mello, Parsons, and Triantis (1995) document a substitution effect between the flexibility of sourcing production and hedging with derivatives in response to exchange rate risk. Gézcy, Minton, and Schrand (2006) in their sample of U.S. pipelines, find that firms that rely on cash holding and storage use less or do not use any derivatives. Regarding the form of the relation between real and financial hedging, in agreement with Gamba and Triantis (2014), I find that the substitution effect between operating and financial flexibility is stronger with high operating leverage and higher effectiveness of hedging with derivatives when the underlying asset of the derivative is highly correlated with the stochastic factor that shocks operating cash flow. Of course, substitution between hedging and inventories is not perfect given the significant joint contribution of these risk management tools reported in Table 2.2 in the "Inventories & Derivative" case for all parameters settings.

Parameters Setting	*Intercept*(μ_0)	*Inventories Ratio*(μ_1)	*Net Worth Ratio*(μ_2)
$Base\,Case$	0.040	-1.389	0.517
$\nu = 0.25$	-0.280	-0.347	0.582
$\nu = 0.75$	-0.011	-0.499	0.397
$fc = 0.6$	-0.098	-0.963	0.561
$fc = 0.7$	0.163	-2.247	0.607
$\rho = 0.5$	0.997	-3.629	0.303
$\rho = 1$	0.698	-9.779	2.515
$\sigma_z = 0.1$	-0.854	1.645	0.707
$\sigma_z = 0.2$	-0.105	-0.292	0.415

Table 2.5. The Negative Relation between Hedging and Inventories. In this table I report the estimates of the regression of hedge ratio of production $h/[g(k,n,z)/z]$ on the inventories ratio $n/(k+n)$ and the net worth ratio $net\,worth/(k+n)$ where $net\,worth = f(k,n,z)+h(F-x)+\ell_n(1-\delta_n)n-liq^n+\ell_k(1-\delta_k)k-liq^k$ and liq^j for $j = k, n$ are liquidation costs due to obligations in the futures contract. Variables are computed on a panel of 10000 firms for 150 periods simulated with the policy functions computed in the "Inventories & Derivative" version of the model. All estimates are statistically significant.

In Table 2.6, I report data on hedging activity of a group of U.S. airline firms taken from Rampini, Sufi, and Viswanathan (2014). Hedging is measured as the fraction of next year fuel expenses hedged with derivatives. I can only measure hedging as a time series average between 1996 and 2009, so I can only compare hedging activity between but not within airlines. For each airline I report also the time average of inventories ratio that I took from COMPUSTAT files by matching airline name. By comparing hedging with inventories ratio I can get information about the degree of substitutability between derivatives and inventories as hedging tools. Even though the limited number of observations precludes any generalization of the results, it is interesting to notice some patterns in the data that confirm the predictions of my model. In Table 2.6, airlines are sorted on hedging activity with derivatives.

First of all, I observe that hedging with derivatives is used more by larger firms in agreement with empirical risk management literature. Secondly, airlines have low inventories ratios compared to firms in other industries because of technological reasons but also because they can hedge fuel expenses more effectively given the lower basis risk between jet fuel and, for example, oil derivatives. Thirdly, I observe that the inventories ratio is decreasing with the hedge ratio and size. For example, in Table 2.6, I observe that airlines with hedge ratio between 0% and 12.5% have higher inventories ratios compared to airlines with an hedge ratio between 12.5% and 25%. This pattern is even more clear if I compare airlines that hedge between 0% and 25% of fuel expenses with those with hedge ratio between 25% and 62.5%. As an extreme observation "GREAT LAKES AVIATION LTD " do not hedge at all with derivatives but it has the highest inventories ratio of 12% on average. The use of pass-through agreements[16] may signal an higher need of hedging, as the hedge ratio for those firms is extremely high. However, the negative relation between hedging with derivatives and hedging with inventories holds also for this group. With the exception of "EXPRESSJET HOLDINGS INC", airlines with pass-through agreements also exhibit a substitution between hedging with derivatives and hedging with inventories. For example, in this group, "MESA AIR GROUP INC" has an hedge ratio in 62.5-75% with an average inventories ratio of 4.65%, while "REPUBLIC AIRWAYS HLDGS INC", that hedges 100% of its fuel exposure, has an average inventories ratio of 1.58%. In summary, this simple comparison of hedging and inventories policies in the airline industry broadly supports my model's predictions, even though the paucity of data makes it impossible to draw any general conclusion.

[16]In pass-through agreements a carrier provide fuel and other services to a regional airline that provide jet service on behalf of the carrier. In this way the airline is naturally hedge against fuel price fluctuations.

Airline	*Hedging*	*Inventories Ratio*	*Pass-through*	*Size*
GREAT LAKES AVIATION LTD	0	12 (10.7)	No	4.57
MIDWAY AIRLINES CORP	0	1.39 (1.42)	No	5.42
US AIRWAYS GROUP INC -OLD	0 - 12.5	2.6 (2.7)	No	9.02
FRONTIER AIRLINES HOLDINGS	0 - 12.5	1.25 (1.19)	No	6.02
MIDWEST AIRRGOUP INC	12.5 - 25	2.29 (2.36)	No	5.64
CONTINENTAL AIRLS INC -CL B	12.5 - 25	2.24 (2.16)	No	9.15
UNITED CONTINENTAL HLDGS INC	12.5 - 25	1.72 (1.68)	No	10.26
NORTHWEST AIRLINES CORP	12.5 - 25	2.17 (2.88)	No	9.48
US AIRWAYS GROUP INC	12.5 - 25	2.92 (3.18)	No	7.74
AIRTRAN HOLDINGS INC	12.5 - 25	1.95 (2.06)	No	6.82
JETBLUE AIRWAYS CORP	25 - 37.5	0.47 (0.48)	No	8.22
ALASKA AIR GROUP INC	25 - 37.5	1.93 (1.89)	No	8.25
DELTA AIR LINES INC	25 - 37.5	0.73 (0.75)	No	10.26
SOUTHWEST AIRLINES	50 - 62.5	1.20 (1.21)	No	9.08
MESA AIR GROUP INC	62.5 - 75	4.65 (3.97)	Yes	6.52
SKYWEST INC	62.5 - 75	2.74 (2.68)	Yes	7.12
MAIR HOLDINGS INC	75 - 87.5	2.85 (3.37)	Yes	5.18
EXPRESSJET HOLDINGS INC	100	5.12 (4.99)	Yes	6.20
PINNACLE AIRLINES CORP	100	2.33 (2.26)	Yes	5.91
REPUBLIC AIRWAYS HLDGS INC	100	1.58 (1.58)	Yes	7.42

Table 2.6. Hedging Policies Comparison. In this table I report the time series average of hedging activity, measured as the percentage fraction of fuel expense hedged, inventories ratio and size, measured as the log of total assets for a group of U.S. airlines between 1996 and 2009 in the sample studied by Rampini, Sufi, and Viswanathan (2014). In column *Pass-through* it is reported whether the airline had or not a pass-through agreement.

2.4.3 The Contributions of Inventories and Cash Holdings to Firm Value

I solve the dynamic programming problem related to the integrated management of capital, inventories and cash holdings using the same set of parameters in Table 2.1 and examine the relative and marginal contribution of inventories and cash holdings to the enterprise value, which is firm value less the cash balance. I call "Cash" the model where the firm controls capital and cash balance while inventories is constant at the unconditional mean, "Inventories & Cash" the model where the firm controls capital, inventories and cash balance. In the benchmark model and in the "Inventories" model the enterprise value coincides with firm value.

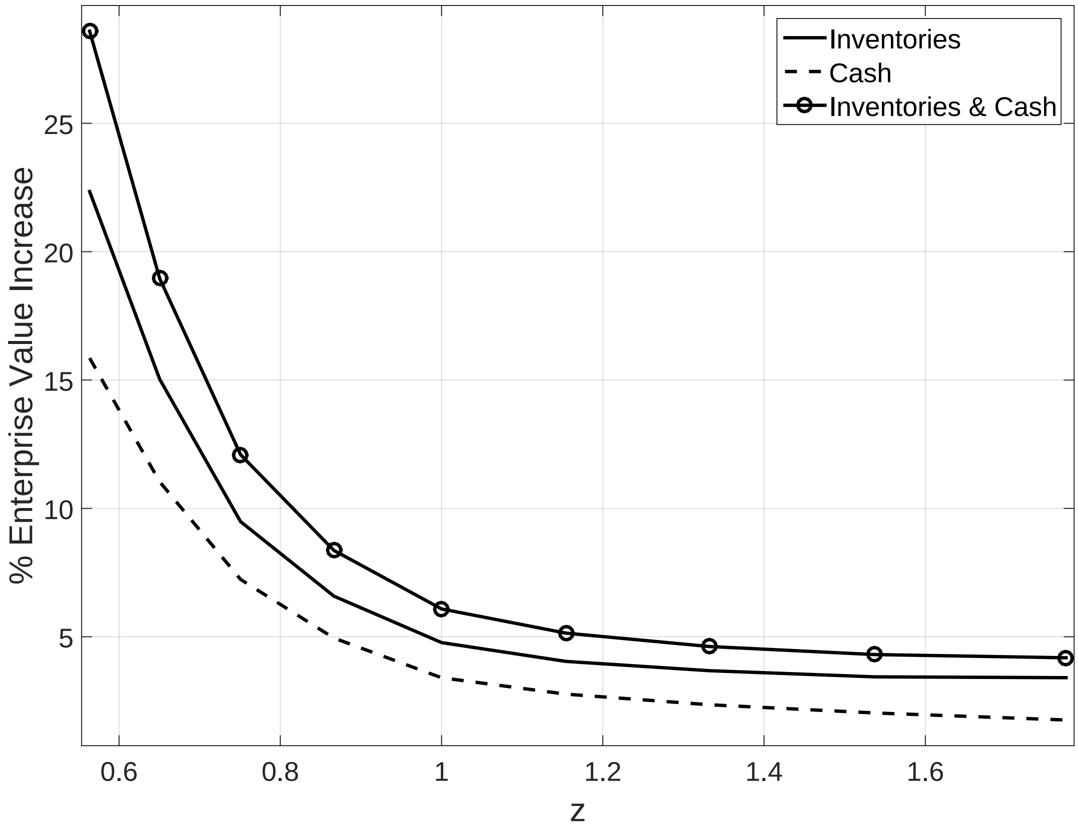


Figure 2.7. The Marginal Contribution of Inventories and Cash Holdings to Enterprise Value. In this figure, I show, against the shock z, average percentage enterprise value increases of inventories, "Inventories" case, and cash balance, "Cash", and the joint contribution of these controls, "Inventories & Cash" case, with respect to the benchmark model in which only capital is controlled. Value increases are shown under base case parameters and for the unconditional average values of k, n and cb, respectively, 2.23, 0.69 and 0.19, computed with simulation of the "Inventories & Cash" model.

In Figure 2.7, I show the percentage value increase in the "Inventories", "Cash" and "Inventories & Cash" cases. In Table 2.7, I report the average percentage enterprise value increases in the same three cases under different parameters settings.[17] Inventories and cash management significantly contribute to enterprise value. Under the base case parameters, the average percentage value increase in the "Inventories" case is 4.77% while in "Cash" case it is 3.40%. As in the previous section, I find that risk management becomes more important if complementarity between capital and inventories increases because of a reduction of substitution flexibility that must be compensated somehow. The average percentage enterprise value increase in the "Cash" case is 3.40% with $\nu = 0.5$, while it is 5.84% with $\nu = 0.75$, also exceeding the marginal contribution of inventories. In general, higher complementarity entails less freedom of adjusting the mix of capital and inventories in response to supply chain shocks, production disruptions or sudden demand increases. Consequently, the firm saves more in response to such a reduced

[17]The contributions to value in the "Inventories" case are different compared to those in Table 2 because they are shown for different levels of the variables in the respective grids.

value of substitution flexibility as I observe in Table 2.8 where cash ratio increases from 6.3% with $\nu = 0.5$ to 9.5% with $\nu = 0.75$.

	1	2	3	4	5	6	7
Variable	$Base\,Case$	$\nu = 0.25$	$\nu = 0.75$	$fc = 0.6$	$fc = 0.7$	$\sigma_z = 0.1$	$\sigma_z = 0.2$
Inventory	4.773	2.269	5.679	2.159	9.525	2.875	5.119
Cash	3.403	1.010	5.844	0.634	5.253	0.818	3.548
Inventory & Cash	6.084	2.998	8.221	2.637	11.235	3.280	7.275

Table 2.7. **Average Percentage Enterprise Value Increases**. In this table I report the average percentage present enterprise value increases due to controlling inventories, "Inventories", controlling cash holdings, "Cash", and controlling inventory and cash holdings "Inventories & Cash", in addition to capital, under different parameters settings. Percentage value increases are reported for the average value of the technology shock $z = 1$ and for the values of control variables in the respective sets closest to unconditional averages of capital, inventories and notional in each parameter setting.

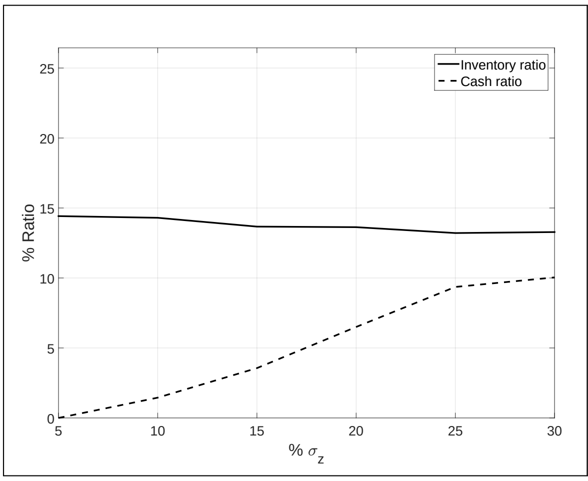
	Variable	Mean	Median	St.Dev.
Base case	Inventories Ratio	0.220	0.220	0.025
	Cash Ratio	0.063	0.048	0.077
$\nu = 0.25$	Inventories Ratio	0.186	0.194	0.018
	Cash Ratio	0.044	0.016	0.063
$\nu = 0.75$	Inventories Ratio	0.234	0.234	0.028
	Cash Ratio	0.095	0.088	0.094
$fc = 0.6$	Inventories Ratio	0.227	0.233	0.021
	Cash Ratio	0.039	0.000	0.063
$fc = 0.7$	Inventories Ratio	0.211	0.215	0.033
	Cash Ratio	0.071	0.048	0.079
$\sigma_z = 0.10$	Inventories Ratio	0.228	0.232	0.015
	Cash Ratio	0.025	0.000	0.043
$\sigma_z = 0.20$	Inventories Ratio	0.208	0.204	0.029
	Cash Ratio	0.104	0.098	0.104

Table 2.8. **Descriptive Statistics of the Model with Capital, Inventories and Cash**. In this table I report, under various model parameters settings, descriptive statistics of inventories ratio $n/(k + n + cb)$ and cash ratio $cb/(k + n + cb)$ of the "Inventories & Cash" model. Unconditional moments are estimated from a panel of 10000 firms for 150 periods simulated with the policy functions computed in the "Inventories & Cash" version of the model.

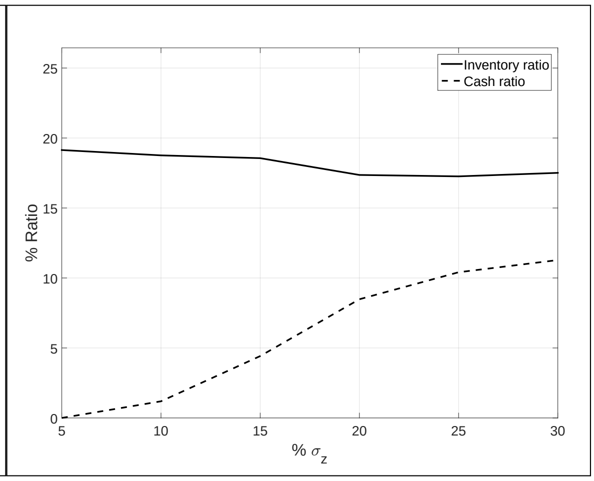
In Columns 4 and 5 of Table 2.7, I show the effect of operating leverage on the contribution to enterprise value of inventories and cash. I find that the percentage value increase due to inventories averages 9.53% while the individual contribution of cash averages 5.25%. In contrast, the contribution of inventories and cash to enterprise value becomes very small with operating leverage $fc = 0.6$, lower than the base case 0.65, with a joint contribution of inventories and cash averaging 3%. This happens because the firm has lower probability to incur external financing costs with low operating leverage and, consequently, there is less need of hedging cash flow. The individual performance of cash holdings falls with lower operating fixed costs averaging 1%. This effect can be seen also looking in Table 2.8 at the drastic decrease of the cash ratio to 3.9% on average and 0% in median.

In Columns 6 and 7 of Table 2.7, I observe that the contribution of inventories and cash to the enterprise value become higher the higher the volatility of the cash flow. As for inventories, the contribution to enterprise value is 2.88% with $\sigma_z = 0.10$ and 5.12% with $\sigma_z = 0.20$. As explained in Pindyck (1982) and Leahy and Whited (1996), when assets are easily reversible, an increase in the cash flow volatility leads to an increase of investment, to take advantage of large increases of z, while (costly) asset allows to absorb negative shocks. Also cash holdings contribute more to enterprise value with higher volatility, in agreement with the precautionary motive for holding cash. More specifically, the individual contribution of cash averages 0.82%, 3.40% and 3.55% with σ_z equal respectively to 0.10, 0.15 and 0.20, and the cash ratio increases from 6.3% with σ_z equal to 0.15 to 10.4% with σ_z equal to 0.20.

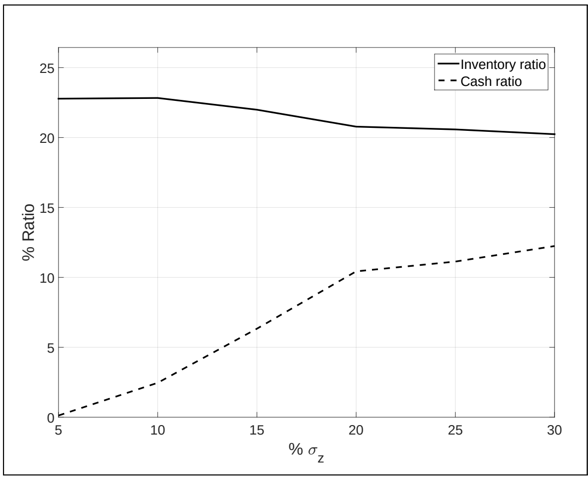
Increasing σ_z and consequently the cash flow volatility leads also to a reduction of the inventories ratio. This result can be attributed to a substitution effect between inventories and cash given the increase of the cash ratio in response to higher cash flow volatility for precautionary reasons. In addition to higher cash flow volatility other operating and technological changes, like improvements in supply chain management or more efficient systems of production, led to a reduction of the contribution of inventories to firm value in the last thirty years. These technological changes can be approximated by a reduction of ν. In Figure 2.8, I observe that the substitution effect between inventories and cash holds under different settings of ν. Complementarity between production factors shifts up inventories ratio which displays in all Panels of Figure 2.8 a convergence pattern as volatility increases. Cash ratio steadily increases with cash flow volatility at a higher rate as ν increases as it can be seen observing how the slope of the dashed line changes from one case to the other. In agreement with Han and Qiu (2007), Gamba and Triantis (2008) and Riddick and Whited (2009) I find support for the precautionary motive for holding cash postulating that higher cash flow volatility leads to higher cash stocks. This result is in line also with Bates, Kahle, and Stulz (2009) who find a substitution effect between the cash ratio and the net working capital (net of cash) ratio that can be attributed, among other factors, to the secular increase in idiosyncratic volatility documented in Campbell, Lettau, Malkiel, and Xu (2001), Comin and Philippon (2006) and Irvine and Pontiff (2009) for the U.S. and reasonably also for the rest of the world.



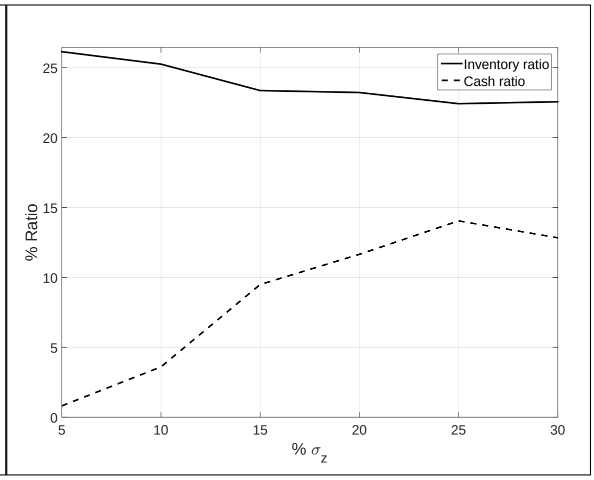
(a) $\nu = 0.01$



(b) $\nu = 0.25$



(c) $\nu = 0.50$ - Base case.



(d) $\nu = 0.75$

Figure 2.8. The Effect of Cash Flow Volatility on Inventories Ratio and Cash Ratio. In this Figure, I show against the technology shock volatility σ_z, the average inventories ratio, $n/(k+n+cb)$, and cash ratio, $cb/(k+n+cb)$, computed on a panel of 10000 firms for 150 time periods simulated with the "Inventories & Cash" model, according to different levels of ν.

In Table 2.9, I report the unconditional correlation between the inventories ratio and the cash ratio in the "Inventories & Cash" case. I observe that the substitution between inventories and cash is driven by both the degree of complementarity between production factors and the technology shock volatility. The negative correlation between inventories ratio and cash ratio becomes stronger as ν increases and also when σ_z is higher. With high complementarity between capital and inventories the latter promises a higher return because it is essential in the production process. However, higher complementarity reduces the flexibility of adapting to technology shocks thereby increasing the need for cash. On the other hand, cash flow volatility crucially determines the return from cash holdings in terms of avoidance of external finance costs but at the same time the reversibility of inventories is enhanced by a more variable business environment. In summary, inventories and cash provide hedging benefits boosted by complementarity and cash flow volatility that influence the strength of the substitution between them.

	$\sigma_z = 0.10$	$\sigma_z = 0.15$	$\sigma_z = 0.20$
$\nu = 0.01$	-0.601	-0.757	-0.827
$\nu = 0.25$	-0.748	-0.856	-0.870
$\nu = 0.50$	-0.842	-0.909	-0.909
$\nu = 0.75$	-0.861	-0.942	-0.946

Table 2.9. Correlation between Inventories Ratio and Cash Ratio. In this table I report unconditional correlation of inventories ratio $n/(k+n+cb)$ and cash ratio $cb/(k+n+cb)$ computed in the "Inventories & Cash" model according to the complementarity parameter ν and technology shock volatility σ_z.

2.5 Empirical Tests

In this section I pursue two objectives. Firstly, I empirically test the predictions of the model previously developed with specific attention to the relation between cash ratio and inventories ratio explained under the risk management perspective. Secondly, I test the relationship between cash flow and inventories investment as a way to test the role of inventories as a reserve of liquidity. This exercise is useful also to assess the significance of the sensitivity to cash flow inventories investment.

I develop the first part of the empirical analysis also on the basis of findings in Bates, Kahle, and Stulz (2009) who find a negative relation between net working capital (net of cash) ratio and cash ratio for U.S. industrial firms in the period from 1980 to 2006. Many factors may explain such findings. First of all, a trend toward liquidity in the choice of production factors can explain a substitution effect between working capital assets. Bates, Kahle, and Stulz (2009) report that the decline in net working capital ratio, mainly due to a reduction of inventories and receivables, has led firms to hold more cash. This argument, although reasonable, misses the important element that cash and other working capital items like inventories are typically endogenously chosen by firms' managers. This fact may lead to significant bias in the estimation of the magnitude and the sign of the relation between variables so that endogeneity must be addressed.

Operating factors cannot completely explain the substitution between inventories and cash holdings. Another factor that may have influenced the negative correlation between these working capital items is the secular increase in cash flow volatility documented in Irvine and Pontiff (2009). Firms facing high cash flow volatility hold more cash for precautionary reasons. At the same time, cash flow volatility seriously also impacts firm's investment policies, including inventories investment. Pindyck (1982) explains that higher uncertainty may lead to higher levels of assets depending on the shape of assets' adjustment costs. In a later contribution, Pindyck (1988) identifies reversibility of investment as of the main factors influencing the relation between risk and investment. Irreversibility makes the marginal revenue from investment a concave function of the stochastic factor driving the revenue itself. Consequently, higher uncertainty translates into lower investment rates. This proposition is empirically confirmed in Leahy and Whited (1996) in a sample of U.S. manufacturing firms between 1981 and 1987.

I analyze the relation between inventories and cash and the effects of cash flow volatility in a sample of U.S. firms, in the same period as in Bates, Kahle, and Stulz (2009), taken from COMPUSTAT Industrial files in 2014. I construct my sample by taking all the universe of firms in COMPUSTAT from which I delete firms with negative or zero values of relevant balance sheet items like total assets, sales, gross capital stock, cash stock, number of shares outstanding, stock price, book equity and observations that do no comply with standard accounting identities. I excluded also firms with total assets below 2 millions of dollars and with fixed capital below one million of dollars to avoid rounding errors. Finally, I excluded from my sample utilities and financial firms with SIC codes between 4900 and 4999 and between 6000 and 6999. My final sample includes a total of 17283 firms between 1980 and 2006.

I define variables basically according to Bates, Kahle, and Stulz (2009) and according to common practice in the finance literature. My dependent variable is the inventories ratio defined as total inventories (invt - #3)[18] over total assets (at - #6). I select from Bates, Kahle, and Stulz (2009) explanatory variables that are likely to explain the inventories ratio. I include the cash ratio defined as the cash and short term securities (che - #1) over total assets. I expect a negative relation between cash ratio and inventories ratio for both operating and risk management reasons. Cash flow is defined as income before extraordinary items (ib - #118) plus depreciation and amortization (dp - #14) and the cash flow ratio is measured as cash flow over total assets. Cash flow is found positively correlated with inventories investment in Carpenter, Fazzari, and Petersen (1994) because budget constraint for investments is reduced when internally generated funds are low and external finance is costly. Moreover, inventories are a very liquid asset that can be liquidated when cash flow is low. However, controlling for investment opportunities may change the sign of the relation between cash flow and inventories

[18] I report between brackets the reference label and number of items as referenced in COMPUSTAT.

ratio. Industry cash flow volatility is constructed in two steps according to Opler, Pinkowitz, Stulz, and Williamson (1999) and Bates, Kahle, and Stulz (2009): firstly, I compute for each time period and for each firm the cash flow volatility using observations of cash flow from the previous 10 years, secondly I average cash flow volatility across firms in industries categorized with the first two-digits of the SIC code. Cash flow volatility should be negatively related to inventories ratio because of reversibility reasons previously explained.

I include in my list of explanatories a measure of investment in fixed capital defined as capital expenditures (capx - #128) over total assets. I expect a negative effect of investment in capital on inventories ratio because of fewer resources available for other types of investment if the firm allocates more resources to capital expenditures. Tobin's Q ratio (market-to-book ratio) proxies for investment opportunities and it is measured as the log of total assets minus book value of common equity (ceq - #60) plus the market value of equity scaled by total asset as in Bates, Kahle, and Stulz (2009). The market value of equity is given by the closing annual stock price (prcc - #199) multiplied by the number of common shares outstanding (csho - #25). I use also two different measures of Tobin's Q related to fixed capital and inventories. Specifically, I compute Tobin's Q of capital as the log of the value of assets minus the book value of inventories over the book value of capital given by gross property, plant and equipment (ppegt - #7). In a similar manner, I compute Tobin's Q of inventories as the log of the value of assets minus the book value of capital over the book value of inventories. I expect a negative and a positive relation, respectively, between market-to-book of capital and inventories ratio and between Tobin's Q of inventories and inventories ratio. Although both capital and inventories investments are driven by future productivity, it is reasonable that there are factors, captured by individual Tobin's Q, that influence the choice between the investment in capital and inventories. To take into account financing of working capital assets like inventories I construct a proxy of short-term financing as the sum of debt in current liabilities (dlc - #34) and trade accounts payable (ap - #70) over total assets. I define size as the log of total assets and I use it as an explanatory of inventories ratio because it is an inverse measure of access to capital markets since large firms obtain external funds more easily than small firms. Inventories are very procyclical and thereby positively correlated with sales. For this reason, as in Jones and Tuzel (2013), I include sales growth, computed as the rate of growth of sales (sale - #12). Finally, I control for leverage computed as the sum of debt in current liabilities and long-term debt (dltt - #9) over total assets. I use leverage to control for financial obligations that may constrain investment in inventories.

In Table 2.8 I report descriptive statistics of the dependent variable of interest, inventories ratio, and other explanatory variables. The average inventories ratio is 16.5% for the whole sample. In agreement with Bates, Kahle, and Stulz (2009) I find that the cross-sectional average of inventories ratio exhibits a decreasing trend in the period from 1967 to 2014. In the same period, cross-sectional average cash ratio and cash flow volatility increased. The secular trends of inventories ratio, cash ratio and cash flow volatility can be clearly observed in Figure 2.9. Inventories ratio averaged 24-30% from 1967 to 1980 and it decreases to an average in 15-20% in the 20 years after 1980. Slightly before the end of the 1990's the inventories ratio averaged in 13-15%. Conversely, cash ratio exhibit a constant positive trend from 1967 to 2014 ranging from a value slightly below 10% in 1967 to a value very close to 20% in the years from 2002 to 2014. Inventories ratio, as well as cash ratio, is very volatile with a standard deviation of 0.159 while the capex ratio is much less volatile, 0.078 on average, indicating that much of the variability in the inventories ratio derives from adjustments in inventories, say, in the numerator or adjustments of other not fixed assets in the denominator of the ratio.

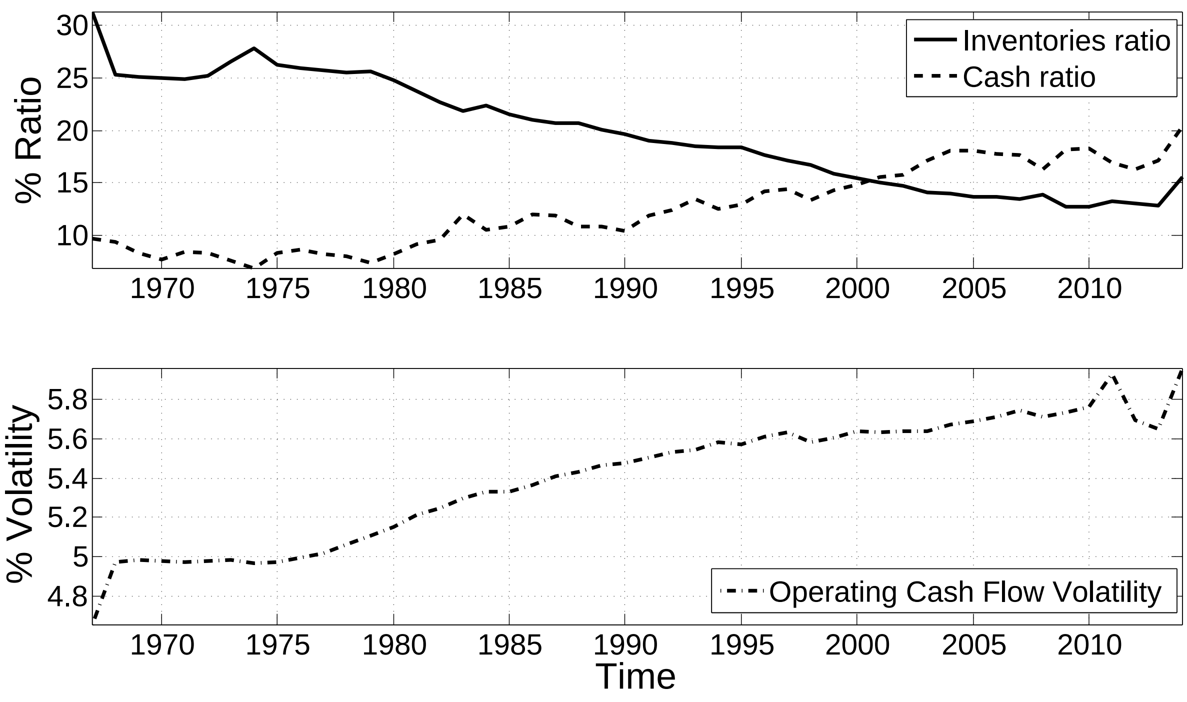


Figure 2.9. The Temporal Trends of Inventories Ratio, Cash Ratio and Cash Flow Volatility. In this figure I depict the cross-section average of inventories ratio, cash ratio and cash flow volatility against time for the whole sample.

Variable	*Mean*	*Median*	*Std*	*Min*	*Max*
Inventories ratio	0.193	0.163	0.159	0.000	0.962
Cash Flow ratio	0.053	0.083	0.198	-10.640	11.07
Industry CF sigma	0.054	0.052	0.018	0.021	0.101
Sales Growth	0.110	0.093	0.340	-9.32	8.557
Cash ratio	0.126	0.063	0.158	0.000	0.981
Tobin's Q	0.422	0.304	0.661	-3.480	6.570
Tobin's Q Capital	1.009	0.836	1.146	-6.677	8.156
Tobin's Q Inventories	1.908	1.690	1.752	-8.356	12.341
Capex ratio	0.074	0.051	0.078	-0.343	2.354
Short-term financing	0.168	0.130	0.135	0.000	1.057
Size	4.924	4.668	2.180	0.693	13.59
Leverage	0.246	0.230	0.188	0.000	1.030

Table 2.10. Sample Descriptive Statistics. In this table I report descriptive statistics of the dependent variable, inventories ratio and of the explanatory variables cash flow ratio, industry cash flow volatility, sales growth, cash ratio, Tobin's Q of total assets, Tobin's Q of fixed capital, Tobin's Q of inventories, capital expenditures ratio, short-term financing, size and leverage.

In Table 2.9 I report estimates of the model specified in Bates, Kahle, and Stulz (2009). In the same manner as in Bates, Kahle, and Stulz (2009), I use also R&D-to-sales ratio, R&D expenses (xrd - #46) scaled by sales, acquisition activity measured by acquisitions (aqc - #129) scaled by total assets, and a dividend dummy, dividend (dvc - #21) equal to one if the firm pays dividends. I replicate results from Bates, Kahle, and Stulz (2009) to ascertain that there are no mistakes in the construction of my sample. The regression estimates have the expected sign. For example, the volatility of cash flow has a positive and significant effect on the cash ratio. Secondly, the sign of the coefficient of inventories ratio is negative and significant across different estimators. Also the coefficients of size, market-to-book and cash flow-to-assets are significant and have the expected sign, in agreement with findings in Bates, Kahle, and Stulz (2009). Finally, the presence of few outliers does not significantly influence estimation. For the explanation of the relation between other variables and cash ratio I refer the reader to Bates, Kahle, and Stulz (2009).

	1	2	3	4
Model	POLS	Changes	Fama-MacBeth	Fixed Effects
Dependent Variable	Cash ratio	Δ Cash ratio	Cash ratio	Cash ratio
Intercept	0.137***	0.007***	0.125***	0.102***
	(0.007)	(0.002)	(0.005)	(0.009)
Δ Cash ratio		-0.067***		
		(0.006)		
L1.Cash		-0.124***		
		(0.003)		
Industry Sigma	0.785***		0.694***	
	(0.083)		(0.182)	
Tobin's Q	0.065***	0.022***	0.064***	0.041***
	(0.002)	(0.001)	(0.003)	(0.002)
Size	-0.003***	0.026***	-0.003***	-0.004***
	(0.001)	(0.003)	(0.001)	0.002
Cash Flow ratio	-0.099***	-0.007***	-0.065***	-0.018***
	(0.006)	(0.005)	(0.011)	0.006
Inventories ratio	-0.051***	-0.079***	-0.048***	-0.076***
	(0.002)	(0.003)	(0.001)	(0.003)
Capex ratio	-0.582***	-0.263***	-0.593***	-0.359***
	(0.017)	(0.010)	(0.041)	(0.013)
Leverage	-0.370***	-0.135***	-0.346***	-0.214
	(0.008)	(0.008)	(0.016)	(0.008)
R&D-to-Sales	0.000	0.000	0.0215**	0.000
	(0.000)	(0.000)	(0.009)	(0.000)
Dividend dummy	-0.041***	0.003*	-0.039***	-0.001
	(0.003)	(0.002)	(0.004)	0.003
Acquisition Activity	-0.302***	-0.185***	-0.308***	-0.218
	(0.015)	(0.010)	(0.030)	(0.012)
Year dummies	Yes	Yes	No	Yes
Adjusted R^2	0.466	0.300	0.043	0.253

Table 2.11. Comparison with Bates, Kahle, and Stulz (2009) Estimates. In this Table I report the estimates of regressions similar to those in Bates et al. (2009). The dependent variable is cash ratio explained by cash flow volatility (Industry Sigma), Tobin's Q, size, cash flow ratio, inventories ratio, capital expenditure ratio, leverage, R&D expenditures (R&D/Sales), a dummy equal to one if firm pays dividend and acquisition activity. For all estimators I use Newey-West (1987) standard errors robust to heteroskedasticity and autocorrelation. For FE estimates I report the within adjusted R-squared. Standard errors of estimates are reported in brackets. Significance levels at 1%, 5% and 10% are indicated, respectively, with ***, **, and *.

The result of the estimation of my empirical model on inventories ratio are reported in Table 2.10. I use as dependent variable the first-difference of inventories ratio because of the high persistence of inventories ratio in levels. Coherently, I adopt the first-difference of cash ratio because the coefficient related to this variable is of interest. In addition, I dynamically specify my model in order to take into account the intertemporal economic mechanisms behind the variables analyzed. According to Arellano and Bond (1991), given that endogeneity cannot be completely excluded, I choose a dynamic specification that at least rules out residuals' serial correlation for which I obtain positive response from the Arellano and Bond (1991) test for second order autocorrelation of residuals. I use several estimators all robust to heteroskedasticity, cross-correlation and autocorrelation of residuals.

In the first column of Table 2.10, I report standard pooled OLS estimates with temporal dummies to take into account cross-correlation effects between firms, say, factors that affect all firms in a given time period. All estimated coefficients have the expected sign except the contemporaneous value of cash flow to assets which is negative. The coefficient related to sales growth is always significant and positive in agreement with business cycle and firm level empirical stylized facts reported in Blinder and Maccini (1991) and widely documented in the inventories literature. This result is coherent with Kahn (1987) who argues that inventories investment is performed in relation to expected sales. Substituting sales growth with expected sales growth, computed through the autoregression of order one of sales growth, does not change the sign of the coefficient. In addition, Belo and Lin (2012) and Jones and Tuzel (2013) emphasize the positive relation between the return from investing in inventories, given by increased sales, and inventories investment itself. The positive relation between sales growth and inventories ratio provides support also to the substitution flexibility proposition. For a given level of complementarity between production factors, firms expecting an increase of sales will probably increase the inventories stock given the high cost of increasing capacity.

The volatility of industry cash flow is negatively related to inventories ratio. Accordingly, the estimated coefficient is negative and significant. The construction of cash flow volatility as a moving average based on historical data limits empirical analysis because of collinearity. Indeed, when I take into account fixed effects with within transformation (Column 4), with first differencing (Column 2 and 5) or with industry dummies (Column 6), industry cash flow volatility must be dropped due to collinearity with fixed effects. Ignoring this technical limitation, my empirical result is consistent with my results in the theoretical part of this work where the increase of cash flow volatility leads to a decrease of the inventories ratio. This can be explained with the strong incentive to hoard cash when cash flow is very volatile. In agreement with this result, I find robust negative coefficients related to contemporaneous and lagged levels of the first-difference of cash ratio even after controlling for industry fixed effects, as in Column 6 of Table xxx, that take into account possible differences in the optimal combination of cash and inventories in operations related to firm's production technology. In summary, I find a strong substitution effect between inventories and cash also at the empirical level. This substitution occurs for both operating and risk management reasons. As for risk management, even if inventories are easily reversible they are a second best choice with respect to cash especially when cash flow is very volatile.

In agreement with the Q theory of investment, I find a significant and positive coefficient for market-to-book ratio of inventories. The shadow value of inventories investment is given by the contribution of inventories to productivity through substitutability with capital and by the relatively easy reversibility. When these two sources of value exceed the cost of adjusting inventories, firms invest more in inventories leading to an increase of the inventories ratio. On the other hand, when fixed assets become profitable, say when capital Tobin's Q increases, firms tend to invest less in inventories in order to deploy resources to more remunerative assets like capital. In agreement with this proposition, the coefficient related to capital Tobin's Q is negative and significant. Moreover, given the strong interaction between market-to-book ratios of different assets I tested and found that capital and inventories market-to-book ratios are jointly significant. The tendency to invest in assets other than inventories is primarily given by the higher return from such investments given binding budget constraints. The coefficient of capital expenditures ratio is negative and significant except when I use GMM-diff estimator. This result corroborates the view that when firms have good investment opportunities in more remunerative assets they do prefer to allocate fewer funds to inventories for a given level of financial resources.

Financially constrained firms are typically small firms and firms with high leverage. Accordingly, I find that both size and leverage are negatively and significantly related to inventories ratio. The coefficient of size is very small when the variable is taken in levels, say when pooled OLS or Fama-MacBeth estimators are used, while it is larger when variables are first-differenced (Column 2 and 5). The negative coefficient in Table 2.10 can be related to the fact that small firms, that cannot afford other forms of hedging like derivatives, at least rely on flexibility provided by inventories. This result is in agreement with the substitution effect between hedging with derivatives and inventories that I find with my model. As for leverage, the negative relation with inventories ratio can be explained with the fact that more leveraged firms have typically fewer funds to allocate to investments because they have to repay debt obligations. Another theory suggests that flexible firms have more chances to shift risk at the expenses of creditors who consequently provide fewer funds. MacKay (2003) provide evidence in this sense finding that while asset substitution can be reasonably controlled through debt covenants, operating flexibility increases the likelihood of risk shifting from managers at the expenses of creditors. Firms with higher inventories ratio may be identified as more flexible by financial intermediaries who decide to cut the supply of credit for them.

In contrast to size and leverage, short-term financing is positively and significantly related to inventories ratio. This result may suggest that firms that more easily obtain trade credit from suppliers invest more in inventories. However, I cannot exclude simultaneous causality since inventories may act as a collateral to obtain credit form suppliers as it is argued in the trade credit literature.[19] In summary, although it is hard to detect the direction of the causal relation between inventories and accounts payable, trade credit and short-term debt are a prominent source of financing for inventories so the correlation between inventories and short-term financing is positive.

In Column 5 of Table 2.10, I directly tackle the issue of endogeneity of explanatory variables. I estimate my model with the GMM-dif estimator from Arellano and Bond (1991) where variables are first-differenced to control for fixed effects and lags in levels of the endogenous variables are used as instruments. Inventories ratio and cash ratio are both the outcome of simultaneous decisions from firm's managers, then if we want to correctly gauge the effect of a variation of cash ratio on inventories ratio we need to instrument cash ratio. I use suitable lags of the dependent variable and lags of the first-difference of cash ratio to take into account endogeneity of lags of the dependent variable and cash ratio. Specifically, I instrumented Δ cash ratio and its lag with the first two lags of cash ratio following the traditional approach of the IV/2SLS estimator. Secondly, I used all available lags of Δ inventories ratio, starting from the second lag, to instrument lags of the dependent variable. As it is explained in Arellano and Bond (1991), the GMM-dif estimator treats panel data as a system of equations, one for each time period. With this method it is possible to exploit more instruments than in standard IV estimators. For each equation a different set of instruments is available because of data availability. For example, in the equation relative to the latest date all lags of the endogenous variable can be used while in the equation of the first date from which the sample starts no lags can be used.

Also capex ratio and short-term financing can be endogenous. Capital expenditures are jointly determined with inventories and cash, then I use the lag of capex ratio as instrument for it. As explained above, it is not clear if inventories determines the level of accounts payable or viceversa then I use the lag of short-term finance as an additional instrument. The lags of capex ratio and short-term finance are used as standard IV's. All instruments are exogenous and relevant as tested with Sargan/Hansen test of overidentifying restrictions. Exogeneity of instruments is guaranteed by the good dynamic specification of the model from which I have

[19] See Petersen and Rajan (1997), Frank and Maksimovic (2004), Burkart and Ellingsen (2004) and Fabbri and Menichini (2010).

excluded lags of variables that were not significant. Lags of explanatory variables are relevant instruments because they are highly correlated with endogenous variables. The economic motives that influence firm's policies are very likely to affect decisions in two consecutive time periods. Consequently, using, for example, the lag of capex ratio as instrument for itself is a reasonable choice. In addition, the actual correlations between endogenous variables and instruments are high and significant. For example, the correlation between Δ cash ratio and lagged cash ratio is -0.323 and the correlation between capex ratio and its first lag is 0.643.

In column 5 of Table 2.10 I report the results of estimates with GMM-dif. The coefficient of Δ cash ratio is -1.174 and significant. The substitution effect between cash and inventories empirically holds also after controlling for endogeneity of cash. The coefficient of Δ cash ratio is very close to the FE estimate. This result is not surprising since for panel datasets with many temporal observations the GMM-dif estimator converges to the FE estimator as pointed out in Alvarez and Arellano (2003). GMM-dif and FE estimates are close also for the leverage coefficient that is negatively related to the inventories ratio. The coefficient of Δ short-term finance is significant and with positive sign also after instrumenting it with its own lag. This supports the well known fact that short-term liabilities, and particularly accounts payable, are the main source of financing for working capital items like inventories. Firms that trade with suppliers willing to extend credit have relaxed financial constraints for investments in working capital assets.

For all estimators used in Table 2.10, the coefficient on the lagged level of cash flow ratio is positive while the coefficient of the contemporaneous cash flow ratio is negative. This result contradicts findings in Fazzari and Petersen (1993) and Carpenter, Fazzari, and Petersen (1994). To be fair, the dependent variable in Carpenter, Fazzari, and Petersen (1994) is investment in inventories while here I focus on the inventories ratio. However, inventories ratio contain information related to investment decisions taken in the past period so the estimates in previous studies can be compared with mine. The analysis of the robustness of the sensitivity of inventories investment to cash flow allows to get more information on two issues. First, correctly estimating if inventories investment reacts to shocks to cash flows clarifies the quality of cash flow sensitivities as a measure of financial constraints also in the case of working capital items. Second, if inventories investment do not significantly respond to cash flow, it is likely that the role of inventories as a reserve of liquidity has been overstated by previous literature.

In the literature studying the effect of financial constraints on real investments particular attention has been devoted to the construction of measures of financial constraints. Fazzari, Hubbard, and Petersen (1988) propose that a good measure of financial constraints is the sen-

	1	2	3	4	5	6
Model	POLS	First Differences	Fama-MacBeth	FE	GMM-dif	POLS Industry FE
Dependent Variable	Δ Inventories ratio	Δ (Δ Inventories ratio)	Δ Inventories ratio	Δ Inventories ratio	Δ Inventories ratio	
Intercept	0.099***		0.085***	0.184***		-0.200***
	(0.008)		(0.014)	(0.020)		(0.068)
L1.Δ Inventories ratio	-0.141***	-0.720***	-0.142***	-0.235***	-0.106***	-0.138***
	(0.013)	(0.012)	(0.013)	(0.013)	(0.008)	(0.012)
L2.Δ Inventories ratio	-0.054***	-0.439***	-0.058***	-0.123***	-0.034***	-0.052***
	(0.009)	(0.012)	(0.009)	0.010	(0.006)	(0.009)
L3.Δ Inventories ratio	-0.034***	-0.206***	-0.037***	-0.076***	-0.022**	-0.034***
	(0.007)	(0.008)	(0.012)	(0.007)	(0.005)	(0.007)
Δ Cash ratio	-1.218***	-0.975***	-1.251***	-1.164***	-1.174***	-1.211***
	(0.031)	(0.029)	(0.045)	(0.032)	(0.034)	(0.031)
L.Δ Cash ratio	-0.154***	-0.499***	-0.145***	-0.246***	-0.193***	-0.157***
	0.027	(0.025)	(0.033)	(0.027)	(0.035)	(0.027)
Industry sigma	-0.340***		-0.328***			
	0.080		(0.116)			
Sales growth	0.221***	0.191***	0.225***	0.218***	0.179***	0.219***
	(0.016)	(0.016)	(0.019)	(0.018)	(0.011)	(0.016)
Cash flow ratio	-0.131***	-0.063***	-0.132***	-0.120***	-0.074***	-0.137***
	(0.022)	(0.027)	(0.027)	(0.026)	(0.026)	(0.022)
L.Cash flow ratio	0.112***	0.136**	0.120***	0.131***	0.204***	0.116***
	(0.023)	(0.027)	(0.034)	(0.026))	(0.023)	(0.023)
Tobin's Q capital	-0.074***	-0.199***	-0.074***	-0.179***	-0.317***	-0.096***
	(0.003)	(0.008)	(0.005)	(0.007)	(0.010)	(0.004)
Tobin's Q inventories	0.023***	0.109***	0.025***	0.096***	0.234***	0.043***
	(0.002)	(0.005)	(0.004)	(0.004)	(0.007)	(0.002)
Size	-0.005***	-0.194***	-0.005***	-0.029***	-0.196***	-0.005***
	(0.001)	(0.014)	(0.002)	(0.004)	(0.010)	(0.001)
Capex ratio	-0.602***	-0.177***	-0.625***	-0.393***	-0.579***	-0.515***
	(0.041)	(0.053)	(0.051)	(0.060)	0.078	(0.043)
Δ Short-term finance	0.313***	0.206***	0.286***	0.277***	0.322***	0.305***
	(0.031)	(0.023)	(0.056)	(0.029)	(0.031)	(0.030)
Leverage	-0.076***	-0.083***	-0.075***	-0.113***	-0.173***	-0.063***
	(0.009)	(0.033)	(0.015)	(0.019)	(0.026)	(0.010)
Year dummies	Yes	Yes	No	Yes	Yes	Yes
Industry dummies	No	No	No	No	No	Yes
Adjusted R^2	0.166	0.512	0.160	0.239	0.164	0.178

Table 2.12. Determinants of Inventories Ratio. In this table I report estimates of my empirical model on inventories ratio. The dependent variable is the first-difference of inventories ratio (Δ inventories/assets) and explanatory variables are lags of the dependent variable, first-difference of cash ratio (Δ cash/assets), industry cash flow volatility, sales growth, cash flow ratio (CF/Assets), Tobin's Q of fixed capital, Tobin's Q of inventories, size, capital expenditures ratio (capex/assets), the first-difference of short-term finance (Δ short-term finance), and leverage (debt/assets). For all estimators I use Newey-West (1987) standard errors robust to heteroskedasticity and autocorrelation. For FE estimates I report the within adjusted R-squared. For GMM-dif estimator I use lags of the dependent variable to instrument lags of the dependent variable, the first two lags of cash ratio in levels to instrument Δ cash ratio, the first lags of capex ratio and short-term finance to instrument capex ratio and short-term finance. For GMM-dif estimators I adopt a two-step moments weighting matrix robust to any form of heteroskedasticity and correlation of residuals. Standard errors of estimates are reported in brackets. Significance levels at 1%, 5% and 10% are indicated, respectively, with ***, **, and *.

sitivity of investment to cash flow arguing that more constrained firms rely more on internally generated funds to finance investments. Kaplan and Zingales (1997) seriously questioned the method used by Fazzari, Hubbard, and Petersen (1988) finding that investments of less constrained firms are more sensitive to cash flow. Kaplan and Zingales (1997) rank firms on the basis of a both qualitative and quantitative measure of financial constraints that more precisely gauges the effect of financing frictions on investment. Erickson and Whited (2000) provide evidence on the influence of errors in measurement of Tobin's Q on the relation between cash flow and investment. To assess the effect of cash flow on investment we need to control for Tobin's Q which measures firm's investment opportunities and this is the method used in Fazzari, Hubbard, and Petersen (1988). However, Erickson and Whited (2000) find that measurement errors in Tobin's Q determine the sign and significance of the regression coefficient of investment on cash flow. Indeed, their robust GMM estimates of the cash flow regression coefficient are never significant and if so the coefficient is negative. Similarly, Riddick and Whited (2009) criticize the findings in Almeida, Campello, and Weisbach (2004) on the cash flow sensitivity of cash on theoretical basis and also because of mismeasurement of Tobin's Q. The results in Table 2.10 can be explained by the fact that, even if internally generated funds enlarge the budget available to the firm, it is not guaranteed that the firm uses those resources for investments because this decision is strongly influenced by investment opportunities and other firm's policies.

To test the significance of the sensitivity of inventories investment to cash flow, first of all I ran the same regressions as in Table 2.10 with a cash flow ratio exactly measured as in Carpenter, Fazzari, and Petersen (1994), say, by dividing cash flow by lagged assets instead of contemporaneous assets level. In this case the coefficient of cash flow ratio is never significant. Secondly, I estimate the following equation

$$\frac{\Delta n_{it}}{assets_{it-1}} = \psi_0 + \psi_1 \frac{\Delta n_{it-1}}{assets_{it-2}} + \psi_2 \frac{CF_{it}}{assets_{it-1}} + \psi_3 \, TobinQ_{it} + \psi_4 \frac{\Delta sales_{it}}{sales_{it-1}} + \varepsilon_{it}, \qquad (2.9)$$

where the dependent variable is the inventories investment ratio, explanatory variables are the lag of the dependent variable, the cash flow ratio, Tobin's Q and sales growth and ε_{it} are i.i.d. errors. Equation (2.9) is similar to the one used in Carpenter, Fazzari, and Petersen (1994) with the addition of Tobin's Q and lagged inventories investment ratio. The latter variable is included to obtain a good specification of the model, confirmed by the rejection of first and second order autocorrelation of residuals tested according to Arellano and Bond (1991). The coefficient of interest is ψ_2 that measures the sensitivity of inventories investment to cash flow. I estimate equation 2.9 with standard POLS, FE and with IV estimator with two groups of instruments. In the first IV estimation, I use the lag of cash flow ratio and the R&D expense-to-assets ratio as instruments for the cash flow ratio. R&D expense is used as a proxy for future growth opportunities in Bates, Kahle, and Stulz (2009) and it is useful to capture growth opportunities not related to assets in place which are likely to be contained in cash flow. Both instruments are valid. I regressed cash flow ratio on its lag, Tobin's Q, sales growth and R&D ratio and I obtained very significant coefficients for both lagged cash flow ratio and R&D ratio with t-statistics respectively of 134.39 and -15.02. In addition, lagged cash flow ratio and R&D ratio are not correlated with inventories investment. I estimated equation (2.9) with lagged cash flow ratio and R&D ratio among the regressors finding not significant coefficient for these two IV candidates. Estimation results are reported in Table 2.11.

	1	2	3	4	5	6	7
Variable	POLS	FE	IV (CF)	IV	Model 1	Model 2	Model 3
Intercept	-0.001	0.017***	0.003	0.008	0.025***	-0.141***	-0.119***
	(0.002)	(0.002)	(0.003)	(0.008)			
Inventories inv. ratio lag	0.026**	-0.069***	0.043***	0.095**			-0.283***
	(0.010)	(0.022)	(0.008)	(0.042)			
CF ratio	0.006***	-0.006	0.015	0.007	0.162***	-0.346***	-0.281***
	(0.002)	(0.005)	(0.010)	(0.013)			
Tobin's Q	0.032***	0.052***	0.030***	0.035**		0.208***	0.193***
	(0.001)	(0.003)	(0.001)	(0.015)			
Sales growth	0.061***	0.059***	0.053***	0.017			-0.003***
	(0.008)	(0.009)	(0.004)	(0.078)			
Time Dummies	Yes	Yes	Yes	Yes	No	No	No
Industry Dummies	Yes	No	Yes	Yes	No	No	No
Adjusted R^2	0.096	0.105	0.156	0.126	0.140	0.202	0.276

Table 2.13. The Sensitivity of Inventories Investment to Cash Flow. In this table I report estimates of equation (2.9). In the third Column, I used lagged cash flow ratio and R&D ratio, R&D expense scaled by total assets, as instruments for cash flow ratio. In Column 4, for IV estimates I use the second lag of inventories investment ratio to instrument lagged inventories investment ratio, lagged cash flow ratio and R&D ratio to instrument cash flow ratio, and the second and third lags of sales growth to instrument sales growth. For estimates in Column 4, Hansen's J test statistics equals 4.184. In Columns 5-7 I report regression estimates of equation (2.9) on a panel of firms simulated with the model in the "Inventories" version presented in previous Sections. Robust standard errors are reported in brackets. In Columns 5-7 I omit standard errors because they are all lower than 0.001. Significance levels at 1%, 5% and 10% are indicated, respectively, with ***, **, and *.

As in Carpenter, Fazzari, and Petersen (1994) the OLS estimate of the sensitivity of inventories investment to cash flow is positive and significant. However, using a very simple estimator like the 2SLS/IV it is possible to see that the significance of ψ_2 estimated with OLS is driven by endogeneity of cash flow. After instrumenting cash flow ratio with its own lag and with R&D ratio, the coefficient related to cash flow ratio is not significant, as it can be seen in Columns 3 and 4 of Table 2.11. In addition, controlling for fixed effects is very important since also in this case the regression coefficient of cash flow ratio is not significant. One explanation for these results is that firms invest in inventories first of all because of future revenues they can get by exploiting operating flexibility, especially substitution flexibility, regardless of cash flow. This means that investment decision is taken mainly on the basis of future revenues even under financial constraints. For example, if the NPV of the investment is positive, firms prefer to invest in inventories and to bear external finance costs instead of liquidating inventories just to avoid raising external finance. Only after controlling for future revenues firms consider liquidating inventories to raise funds.

Liquidation of asset is always among the last financing options because it is costly also for liquid real assets like inventories. In addition, when the firm is experiencing a low cash flow managers may decide to invest rather than disinvest in inventories because they are probably expecting an higher product demand. This mechanism explains why in the numerical results of Section 2.4 we observed no effect of the asymmetry of the investment cost function on the contribution to value of inventories, simply because inventories are rarely used as a source of liquidity. In summary, the sensitivity of inventories investment to cash flow does not seem to be a good measure of financial constraints, first of all because investment is determined by its expected returns. Secondly, since inventories investment is not sensitive to cash flow, inventories are probably rarely used as a reserve of liquidity. As a further evidence, even if Carpenter, Fazzari, and Petersen (1994) in their estimates control for unexpected variation of product demand they do not control for future investment opportunities, say, they do not control for Tobin's Q. Then, their results are probably biased for this reason.

As a further robustness check of my results, I estimate equation (2.9) instrumenting sales growth with its own second and third lags and inventories investment ratio with its own second lag, in addition to the two IV's for cash flow ratio. The use of the lags of sales growth as IV is suggested in Dasgupta, Li, and Yan (2014) where sales growth is used as a measure of production costs shocks that affect operating cash flow and consequently the inventories investment. The concern about exogeneity of sales growth is raised in Dasgupta, Li, and Yan (2014) because sales are to a certain extent endogenously determined jointly with investment decisions. In Column 3 of Table 2.11 I report the results of IV estimates with the additional instruments for sales growth. The coefficient on sales growth is not significant further confirming that measures of internally generated funds, like cash flow ratio or sales growth, are not significantly linked to inventory investment, then they are not good measures of financial constraints. Even Dasgupta, Li, and Yan (2014) find that inventory investment, regardless of financial constraints, is not responsive to negative sales growth.

To compare my model's predictions with empirical data, in Columns 5-7 of Table 2.11, I reported the estimates of equation (2.9) on a panel of firms simulated with the "Inventory" version of my model. Inventories investment ratio is $(n' - n)/(k + n + cb)$, cash flow ratio is $f(k, n, z)/(k+n+cb)$, Tobin's Q is $value(k, n, z)/(k+n+cb)$ where $value(k, n, z)$ is firm value, and sales growth is proxied with the growth rate of the shock $(z' - z)/z$. From simulated data, in Column 5, cash flow has a positive effect on investment. This result may lead to think that internal funds concretely influence the possibility to finance investment in real assets. However, when I control for the return from inventories investment with Tobin's Q, the regression coefficient of cash flow becomes negative indicating that more financially constrained firms invest in inventories when, according to the theory of Fazzari and Petersen (1993), they should liquidate to raise funds. The explanation for this result derives from the sensitivity of inventories investment to future revenues. Regressing inventories investment on cash flow ratio alone bias the estimate because cash flow contains information about future revenues from investment given the persistence of z.

In Column 5-7 of Table 2.11, also the regression coefficient on sales growth is negative, although very small. In contrast to Dasgupta, Li, and Yan (2014), I find that firms invest more in inventories when sales decline. They use sales growth as a proxy for exogenous production costs factors that negatively affect firm's cash flow and consequently investment decisions. However, I find the opposite result on simulated data. Empirically, after controlling for endogeneity of sales growth, the regression coefficient on sales growth is no more significant. In summary, my results indicate that not only cash flow but also sales growth regression coefficients are poor measures of the inventories investment sensitivity to financial constraint, given the forward-looking nature of investment decisions.

As a final comment, I draw a few conclusions on my empirical work. First, all explanatory variables used to predict inventories ratio are found significant and with the expected sign across different estimators. This confirms relationships between variables identified in other studies and support the results from my model. In particular, I empirically found a significant negative relation between cash ratio and inventories ratio supporting the view of these two working capital items as substitutes at both the operating and risk management levels. In addition, I empirically provided evidence on the negative relation between cash flow volatility and inventories, in support of my model's predictions. Although cash flow volatility plays a stronger role to explain cash, inventories ratio is also clearly dependent on cash flow volatility and on the uncertainty of the firm business in general. Reversibility makes the return from inventories positively dependent on cash flow volatility. Second, firm fixed effects play a significant role to explain inventories ratio variability and they must be taken into account using suitable estimators like FE or first-differences that transform data in order to capture unobservable firm-specific heterogeneity. Third, in agreement with other contributions that study the effect of financial constraints on real investments, I find no significant relation between cash flow and inventories investment because of the endogeneity of cash flow. This result is a further signal of the scarce validity of cash flow sensitivity as a measure of financial constraints. Furthermore, the unsignificant sensitivity of inventories investment to cash flow puts in serious doubt the role of inventories as a reserve of liquidity, especially when cash flow is uncertain and firms can rely on cash holdings.

Chapter 3

Inventories as Collateral in Trade Credit Contracts

3.1 Introduction

As an extension of my work on inventories, in this Chapter I study the interactions between inventories, trade credit and cash holdings. The first objective is to show that even if trade credit is typically considered a flexible form of short-term financing it requires guarantees to suppliers that act as creditors. Consequently, trade credit imposes significant costs which bound its effectiveness as a liquidity source leaving firms to prefer other risk management tools like cash holdings. The second objective is to shed more light on the cross-sectional relations between inventories, accounts payable and cash holdings. As we have already observed in the previous Chapter, accounts payable and inventories are positively related. this the sign of the relation is mainly determined by the role of inventories as collateral in trade credit contracts. In the trade credit literature, relatively little attention has been devoted to the relation between accounts payable and cash holdings. These two working capital items are bounded by both operating and risk management factors. At the operating level, accounts payable substitute for cash in the procurement of variable production inputs. At the risk management level, the possibility to rely on credit from suppliers lowers the value of cash holdings against shocks to cash flows. However, accounts payable and cash may also be complement. Indeed, firms may need cash to repay trade credit and to avoid liquidation of inventories due to obligations in trade credit contracts.

Trade credit represents a significant component of firms' short-term financing sources. Rajan and Zingales (1995) report that firm-level average of accounts receivable and accounts payable ranged, respectively, between 13% and 29% and between 11.5% and 17% of firm total assets in their sample of the G7 countries in 1991 from Global Vantage. More recently, Garcia-Appendini and Montoriol-Garriga (2013) report an average accounts receivables-to-sales ratio of 61% in a COMPUSTAT sample of U.S. firms between 2005 and 2010. Marotta (2005), in a survey-based sample, finds that Italian firms finance almost 100% of input purchases with payables. With regard to the incidence of trade credit contracts, recent empirical evidence in Klapper, Laeven, and Rajan (2012) suggests that trade credit is not confined to small, risky and financially constrained firms as once believed. In addition, trade credit involves firms from all industries. Trade credit terms are uniform and stable over time within industries while there is considerable between variation across industries as reported in Petersen and Rajan (1997) and Ng, Smith, and Smith (1999).

Here, I focus on the demand side of trade credit and especially on the relation between inventories and trade credit. My first contribution is to shed further light on the motives that lead firms to ask credit to their suppliers from a risk management perspective. Specifically, I focus on firm-level financial flexibility provided by AP assuming no adjustment costs for varying the level of trade credit asked. From an operating point of view, Ferris (1981) argues that a properly organized payment system between the supplier and the customer largely reduces payment and receivables factoring transaction costs. In addition, trade credit does not entail flotation costs and is less exposed to asymmetric information costs because suppliers know customers better than traditional creditors like banks. Lewellen, McConnell, and Scott (1980) explains how trade credit is irrelevant in a Modigliani-Miller world with no information asymmetries that limits the supply of bank lending.[1] However, information asymmetries cannot be completely erased also in trade credit contracts. This leads suppliers to require a guarantee of repayment at expiration of the contract. In my model this guarantee takes the form of collateral based on inventories stock in agreement with Petersen and Rajan (1997) and Frank and Maksimovic (2004). Alternatively, the supplier may charge a risk premium above the risk-free interest rate.

In contrast to my study, the vast majority of literature on trade credit has rather focused on theories explaining motives for granting credit from the supplier point of view assuming trade credit demand as given.[2] Few contributions have specifically studied buyers' motivations for

[1]Trade credit is considered as a way to circumvent adverse selection and moral hazard problems that restrict traditional lending from financial institutions. Suppliers obtain information on customers' businesses and can liquidate trade credit collateral much more easily and less costly than banks. The better enforceability of credit makes suppliers willing to grant credit when banks are not. See Emery (1984), Mian and Smith (1992), Petersen and Rajan (1997), Burkart and Ellingsen (2004) and Fabbri and Menichini (2010).

[2]For example, Nadiri (1969) treats AR as a production factor in the same manner as capital, Schwartz (1974)

asking trade credit. Ferris (1981) proposes a payment transaction costs theory for both suppliers and buyers. Organized payments make suppliers incur less frequently in costs of credit recover and let liquidity available to customers. Lee and Stowe (1993) and Emery and Nayar (1998) study the customer's incentive to delay payment in order to inspect product quality. I also focus on the study of the effects *firm-specific* liquidity shocks to customers' cash flows on trade credit as in Cunat (2007). In contrast, a large strand of literature has analyzed the impact of macro liquidity provision on trade credit, concentrating on monetary policy, financial crisis and overall financial system development.[3]

Of course, AP are not the only tool to manage liquidity and cash flow risk in general. Besides derivatives hedging, insurance, operating flexibility, cash holdings help in avoiding costs created by liquidity shortage. As explained in Gamba and Triantis (2008), cash is a valuable source of flexibility when firms face debt adjustment costs. Trade debt adjustment costs are almost non-existent but the very motivation that may lead firms to choose cash instead of trade credit is the liquidation cost of inventories due to obligations in trade credit contracts. In the present study, I explicitly compare financial flexibilities embedded in AP and cash. I exploit the basic structure of the model developed in the previous Sections to study the interactions between inventories, trade credit and cash holdings. Specifically, I model trade credit as contingent source of funds that allows firms to avoid costs related to external finance triggered by negative shocks on cash flows. However, trade credit is not a costless financing alternative because of supplier's collateral requirements and the possibility to liquidate inventories to meet obligations in the trade credit contact. Petersen and Rajan (1997), Frank and Maksimovic (2004), Burkart and Ellingsen (2004) emphasize the role of inventories as collateral of trade credit. In agreement with this view, I impose a collateral on trade credit given by the outstanding stock of inventories that can be repossessed and resold by suppliers. Because of the collateral, trade credit can be repaid at the risk-free interest rate since the firm will always be able to repay trade debt even at the cost of liquidating inventories.

Even if firms can alternatively use cash or AP to purchases inputs, AP and cash respond also to other factors like investment opportunities. It is widely known in the trade credit literature that AP are not used to finance long-term investments, then there exists a specific role for cash not covered by trade credit. Cunat (2007) model admittedly misses an important stylized fact

proposes a supplier driven financing motive for granting trade credit, Smith (1987) and Cunat (2007) rely on supplier asset specificity as the main reason for granting trade credit, Brennan, Maksimovic, and Zechner (1988) focuses on suppliers' price discrimination through trade credit, Petersen and Rajan (1997) focuses on better credit enforceability of trade credit by suppliers.

[3] See Meltzer (1960), Brechling and Lipsey (1963), Demirguc-Kunt and Maksimovic (2001), Fisman and Love (2003), Choi and Kim (2005), Guariglia and Mateut (2006), Garcia-Appendini and Montoriol-Garriga (2013).

regarding the joint use of AP and cash by firms. In Cunat's model all firm's available funds are invested in projects with always positive NPV so that no cash is hold. This negative relation between AP and cash, however, is not supported by previous empirical studies. Petersen and Rajan (1997) find a positive, although not significant, coefficient for cash in their estimates of AP determinants. Wu, Rui, and Wu (2012), studying a sample of listed Chinese firms, conclude that more cash is hold to repay AP in the future. This reasoning is in agreement with the transaction costs motive for holding cash since may be costly for the firm to find liquidity to repay AP. Firms save also for precautionary motives and I take into account this incentive thanks to the dynamic nature of our model where investment opportunities are stochastic.

3.2 Model

I assume risk neutral investors and a discrete-time environment with infinite horizon. The firm is all-equity financed. I distinguish current period from next period variables indicating the latter with a prime.

3.2.1 Technology

The firm uses input of production homogeneous across suppliers. Firm's operating profit is given by revenues, defined by a neoclassical CES production technology $g(k, n, z)$, less operating fixed costs fc

$$f(k, n, z) = g(k, n, z) - fc = \left[\alpha k^{-\nu} + (1-\alpha) n^{-\nu}\right]^{-\frac{\theta}{\nu}} - fc, \tag{3.1}$$

where $z > 0$ is a technology shock that determines the state of the firm business. The operating profit function $f(k, n, z)$ is presented in reduced form with respect to the input provision decision. I assume that the optimal quantity of input to be purchased by the firm has been already optimized and substituted for, so that the operating profit function is left as a function of the stock of capital $k \geq 0$, the stock of inventories $n \geq 0$ and the technology shock. $\alpha \in (0, 1)$ is the relative contribution of capital to output, $\nu \in (0, \infty]$ measures the degree of complementarity between capital and inventories and $0 < \theta < 1$ is the returns-to-scale parameter. The natural logarithm of the technology shock $\log(z)$ follows an AR(1) process

$$\log(z') = \phi \log(z) + \sigma_z \varepsilon_t^z,$$

where the autoregressive parameter satisfies $|\phi| < 1$, σ_z is the conditional standard deviation of z and ε_t^z are i.i.d. shocks with Normal distribution truncated within three times the unconditional standard deviation. Investment in capital and inventories is defined as

$$\begin{aligned} I^k = &\quad k' - (1-\delta_k)k, \\ I^n = &\quad n' - (1-\delta_n)n \end{aligned}$$

where I_t^j and δ_j, for $j = k, n$, are investments and depreciation rates, respectively, for capital and inventories. Inventories depreciation includes all costs of carry such as opportunity costs, risk costs (obsolescence, damages, thefts), storage costs and insurance costs. The firm purchases capital and inventories at unit prices if investment is positive, at prices ℓ_k and ℓ_n if assets are liquidated. Adjustment costs for capital are given by

$$ACK(k, I^k) = \frac{\xi^k}{2}\left(\frac{I^k}{k}\right)^2 k, \tag{3.2}$$

where $\xi^k = \xi_k^+ \cdot \chi_{\{I^k \geq 0\}} + \xi_k^- \cdot \chi_{\{I^k < 0\}}$ is the capital adjustment cost parameter that embodies the asymmetry between increasing and reducing the stock of capital as in Zhang (2005).[4] Adjustment costs for inventories are given by

$$ACN(n, I^n) = \frac{\xi^n}{2}\left(\frac{I^n}{n}\right)^2 n, \tag{3.3}$$

where $\xi^n = \xi_n^+ \cdot \chi_{\{I^n \geq 0\}} + \xi_n^- \cdot \chi_{\{I^n < 0\}}$ is the inventories adjustment costs parameter. McCarthy and Zakrajsek (2000) and Belo and Lin (2012) provide evidence on the asymmetry of the adjustment cost function also for inventories. I set $\ell_k < \ell_n$ and $\xi_k^+ > \xi_n^+$ and $\xi_k^- > \xi_n^-$ to emphasize the higher degree of liquidity of inventories.

3.2.2 Financial Policies

In each period inputs can be paid using cash or credit (purchase on account). In the second case, the supplier extends credit to the firm, for one period, requiring the payment of the nominal value *ap* at expiration of the credit. In the same moment an input provision deal is arranged, the supplier is granting an option to pay later to the buyer even if at higher cost. The use of trade credit entails an intertemporal trade-off between the avoidance of liquidity shortage costs today and the future cost of repaying the amount borrowed. I assume, as in

[4] $\chi_{\{A\}}$ is an indicator function of event A.

Schwartz (1974), Emery (1984) and Cunat (2007), deep-pocket suppliers, always willing to extend credit, in order to focus on demand of trade credit. It is widely recognized in the literature that suppliers should have enough financial resources to be able to extend credit to buyers. Another typical requirement is that suppliers should not be credit constrained. Garcia-Appendini and Montoriol-Garriga (2013) stress that liquidity and easy access to financing are two fundamental characteristics of suppliers that grant credit. However, there are situations in which also financially constrained suppliers extend trade credit. Boissay and Gropp (2007) argue that a firm is willing to provide credit whenever credit is received from its suppliers. Boissay and Gropp (2007) find evidence of credit flowing along chains of firms starting from a sufficiently liquid firm at the beginning of the chain. Then, a firm, to grant trade credit, does not need to have access to financial markets but just to trade credit offered by its suppliers. Finally, if we consider trade credit as a selling expense in the same manner as in Nadiri (1969), suppliers are always eager to extend credit because in this way they can increase sales. Bougheas, Mateut, and Mizen (2009) show that for the seller is preferable to extend credit financed-sales instead of carrying costly inventories.

Trade credit must be collateralized so that at expiration of the credit period the amount to be repaid by the firm ap must not exceed the liquidation value of inventories outstanding, $ap \leq \ell_n(1-\delta_n)n$. I also assume that buyers that do not meet debt obligations are not excluded from future trading relationships with any supplier. I assume that the whole stock of inventories can be used as collateral. However, in real contract only a fraction of inventories may be used as a guarantee reflecting many factors that influence the recovery of inputs by suppliers. Firstly, suppliers' seniority is considered important by Frank and Maksimovic (2004) who classify trade credit as unsecured debt because of the low probability of recovering collateral due to banks' priority at default. Secondly, the composition of collateral matters as well. Trade credit collateral is typically given by inventories of raw materials and products that can be easily resold by suppliers (Petersen and Rajan (1997), Frank and Maksimovic (2004)). The further a product goes through the production process the higher the liquidation costs faced by suppliers that exploit their selling channels to resale inputs. Thirdly, collateral characteristics are important. For example, Fabbri and Menichini (2010) theoretically demonstrates that buyers of services receive less credit than buyers of tangible products. This fact is implicitly confirmed in the empirical work of Ng, Smith, and Smith (1999) who find evidence on cross-industry variability and within-industry stability of trade credit contract terms. Furthermore, Fisman and Love (2003) provide empirical support to trade credit theory based on product characteristics in Mian and Smith (1992) and Frank and Maksimovic (2004). According to these studies, in industries where inputs are homogeneous across buyers, inputs inventories are easily resellable. This leads to higher amounts of credit granted by suppliers because of the better quality of buyer's collateral.

Cash is another tool to preserve liquidity. According to the precautionary motive, firms hoard cash in order to meet future obligations without incurring in payment transaction costs (Miller and Orr (1966)). In addition, firms save to avoid costs of liquidity shortage that become more likely the higher the volatility of cash flow. External finance costs can be avoided by saving cash or by contingently asking trade credit. Thus, cash can be thought as a substitute of AP from a risk management perspective.

Because of the possibility to liquidate inventories to meet obligations on trade credit, inventories investment (disinvestment) can be larger (lower) implying a loss for the firm equal to the part of ap not covered with internal funds $f(k,n,z)+(1+r)cb$. Consequently, the investment in inventories must be modified as

$$I^n = n' - (1-\delta_n)n + \frac{1}{\ell_n}\max\{ap - f(k,n,z) - (1+r)cb, 0\}.$$

3.3 Firm's Problem

The firm's cash flow is

$$\begin{aligned} cf(u,u',s) = f(k,n,z) + (1+r_{cb})cb - ap + \frac{ap'}{1+r} \\ - cb' - \eta_k\Big(I^k;\ell_k\Big) - \frac{\xi_k}{2}\left(\frac{I^k}{k}\right)^2 k - \eta_n\Big(I^n;\ell_n\Big) - \frac{\xi_n}{2}\left(\frac{I^n_t}{n}\right)^2 n, \quad (3.4) \end{aligned}$$

where

$$\eta_j\Big(I^j;\ell_j\Big) = \begin{cases} I^j & \text{if } I^j \geq 0 \\ \ell_j I^j & \text{if } I^j < 0 \end{cases}$$

for $j = k, n$.

Operating profit, $f(k,n,z)$, plus the amount $ap'/(1+r)$ saved thanks to trade credit, and cash proceeds, $(1+r_{cb})cb$, determine the funds available that are allocated to next period cash cb', capital k', inventories n' and to repayment of trade credit ap. I underscore that liquidity shortage can be generated by both operating and financial factors. Indeed, fixed operating costs and assets depreciation, in the same manner as AP repayment, contribute to absorb funds that may be alternatively allocated to profitable investment opportunities.

The assumption of compact support for $\log(z)$ translates into the compactness of the set $\mathcal{Z} = [z_l, z_u]$. I assume capital and inventories take value, respectively, in $\mathcal{K} = [0, k_u]$ and $\mathcal{N} = [0, n_u]$ where k_u and n_u are chosen as explained in the Appendix. ap takes value in $\mathcal{P} = [0, \ell_n(1-\delta_n)n]$. The lower bound derives from our assumption of no cash flow from the buyer to the seller. I exclude cash flow from customers to suppliers in the form of prepayment of inputs since I concentrate on customer flexibility to ask for credit. The upper bound is defined in each period by $\ell_n(1-\delta_n)n$ because of the limit imposed by suppliers on the credit granted with the collateral constraint. $\mathcal{C} = [0, cb_u]$ is the compact set for cash stock with upper bound cb_u determined by the economic convenience for holding cash. Specifically, cb_u is chosen large enough so that retaining an amount of cash larger than cb_u is not profitable. The benefit of holding cash is the possibility to cope with financing needs in the future and to have funds available to repay suppliers while the cost is given by the lower amount of funds available to be invested elsewhere. Such an opportunity cost, in addition to the interest penalty $r_{cb} < r$ on savings, ensures an upper bound to retained cash stock.

The hyper-rectangle $D = \mathcal{K} \times \mathcal{N} \times \mathcal{P} \times \mathcal{C} \times \mathcal{Z} \in \mathbf{R}^5$ is a convex and compact set. The four control variables k', n', ap' and cb' take value in the feasible set $\Gamma(u,z)$ where $u = \{k, n, ap, cb\}$. $\Gamma(u,z)$ is non-empty, compact-valued and continuous because it is a function of compact-valued and continuous variables. The cash flow in (3.4) is bounded (because it is defined on a compact and continuous set) and continuous. I compute firm value $v(u,z)$ by numerically solving the Bellman equation

$$v(u,z) = \max\left\{\max_{u'\in\Gamma(u,z)}\left[cf(u,u',z) + \chi_{cf(u,u',z)<0}\Lambda(cf(u,u',z)) + \beta\mathbb{E}_{u,z}v(u',z')\right], 0\right\}, \quad (3.5)$$

where $\beta \in (0,1)$ is a deterministic discount factor, $\mathbb{E}_{u,z}$ is a conditional expectation under the risk neutral probability measure Q equipped with the Feller property, and $\Lambda(cf(u,u',z))$ is the external finance cost function similar to that used in the previous Chapter. Firm value is given by the unique and continuous function $v : D \to \mathbf{R}^+$ satisfying (3.5) (Stokey and Lucas (1989), Ch. 9, Th. 9.6.) that can be found with the method of *successive approximations*. In addition, firm value function is monotonically increasing in capital and cash and monotonically decreasing in accounts payable (Stokey and Lucas (1989), Ch. 9, Th. 9.7.) . Finally, given the concavity of the firm value function, provided by functional form of the cash flow function, the optimal policy function is unique and continuous (Stokey and Lucas (1989), Ch. 9, Th. 9.8.).

3.4 Results

In this Section I study the relationships between accounts payable ratio, inventories and cash holdings by comparing regression estimates on a simulated panel of firms and on the same sample of U.S. firms used in the Section 2.5 of Chapter 2. I calibrate the model on trade credit using then same parameters as in Table 2.1. In addition, I calibrate the parameters of the adjustment cost functions of capital and inventories. In literature, the parameter ξ_k^+ of capital adjustment costs is typically estimated between zero and 2.2. Hall (2004) reports a range of values between zero and one which is lower than Shapiro (1986) estimate of 2.2. Whited (1992) finds an adjustment cost parameter between 0.5 and 2. I select 1.25 as the base case parameter which is also the value chosen by Zhang (2005). To set ξ_k^- I rely on Zhang (2005) choice of $\xi_k^+/\xi_k^- = 1/10$ taken from Hall (2001). Evidence on the magnitude of adjustment costs for inventories is quite scarce. Chirinko (1993) and Hall (2000) report small inventories adjustment costs. In addition, we know that they are lower than capital adjustment costs because of the relatively higher reversibility of inventories compared to capital. From Jones and Tuzel (2013) estimates I derive a ratio $\xi_k/\xi_n = 25$ for both ξ_n^+ and ξ_n^- consistent with the level of $\nu = 0.5$. Given this guidance on the relative magnitude of inventories adjustment costs, I set $\xi_n^+ = 0.05$ and $\xi_n^- = 0.5$.

I estimate a regression with accounts payable as dependent variable and inventories ratio and cash ratio as the main explanatory variables in addition to Tobin's q (or market-to-book ratio) and size (log of assets)

$$\left(\frac{ap_{it}}{assets_{it}}\right) = \gamma_0 + \gamma_1\left(\frac{n_{it}}{assets_{it}}\right) + \gamma_2\left(\frac{cb_{it}}{assets_{it}}\right) + \gamma_3\, TobinQ_{it} + \gamma_4\, size_{it} + \eta_{it}, \tag{3.6}$$

where $assets_{it} = k_{it} + n_{it} + cb_{it}$. The regression is estimated on a panel of firms simulated with my model for 10000 paths and 200 time periods, excluding the first 50 observations for each firm to avoid biased results because of the arbitrary initial values assigned to variables.

My hypothesis is that if cash and accounts payable are substitute, at both the operating and risk management levels, there exists a negative relationship between these two variables. Fabbri and Menichini (2010) underscores that trade credit is particularly relevant for financially constrained firms that can rely on suppliers' credit when internal funds are scarce. However, there may exist also a transaction motive explanation that makes accounts payable positively related with cash holdings. Indeed, even if accounts payable provide valuable contingent financing, it also true that trade credit must be repaid in the future.

Also important is the relation between trade credit and the collateral pledgeable by the firm. If the buyer firm has enough inventories the supplier will provide credit. I cannot differentiate firms on the basis of input standardization or how much input have been transformed by the production process of the buyer. These two characteristics may moderate the supposed positive relation between inventories and account payable. My second hypothesis is that inventories and accounts payable are positively correlated. Finally, accounts payable are expected to be inversely related to size. The negative relationship between size and accounts payable is explained by the fact that small firms are typically financially constrained and ask more actively trade credit. Even if in Petersen and Rajan (1997), Marotta (2005) and Fabbri and Menichini (2010) it is emphasized that not only financially constrained firms obtain trade credit, it is widely accepted in the literature that trade credit displays its beneficial effects more on small, risky and financially constrained firms.

	1	2	3	4
Variable	Simulated	POLS	FE	POLS Industry FE
Intercept	0.010	0.101	0.141	0.041
	(0.001)	(0.003)	(0.004)	(0.005)
Inventories/Assets	0.010	0.165	0.127	0.127
	(0.001)	(0.006)	(0.007)	(0.007)
Cash/Assets	0.032	-0.094	-0.071	-0.087
	(0.001)	(0.004)	(0.003)	(0.004)
Size	-0.186	-0.002	-0.011	-0.004
	(0.001)	(0.001)	(0.001)	(0.001)
Sales growth		0.009	0.010	0.008
		(0.001)	(0.001)	(0.001)
Leverage		-0.041	-0.024	-0.041
		(0.003)	(0.002)	(0.003)
Time Dummies	No	Yes	Yes	Yes
Industry Dummies	No	No	No	Yes
Adjusted R^2	0.488	0.154	0.110	0.250

Table 3.1. **Working Capital Items Relations**. In this table I present estimates of equation (3.6) with a panel of firms simulated with my model and estimates of a sample of U.S firms between 1980 and 2006. POLS refers to pooled OLS estimates, FE refers to fixed effects estimates. Both POLS and FE estimates are performed with Newey and West (1987) standard errors robust to heteroskedasticity and autocorrelation of residuals. For fixed-effects estimates in Column 3 I report within R^2. All estimates are significant at 1% level.

In Table 3.1 I report estimates of equation (3.6) performed on a panel of firms simulated with my model and with the sample of U.S. firms between 1980 and 2006 that I used in the previous chapter. Firstly, I observe that in the simulated panel the transaction cost motive is prevalent on the risk management motive for demanding trade credit by firms. The coefficient of cash ratio is positive and equal to 0.032. This result is due to the fact even if accounts payable are a flexible source of financing they are, at the same time, a liability for the firm. On the other hand, cash provide a way to manage cash flow risk and to meet financial obligations without incurring liquidation costs in general and liquidation costs due to accounts payable. In summary, in my model firms demand trade credit and hold cash which are not substitutes because of the need to save in order to pay obligations from account payable. Empirically, the story is different. In Columns 2 and 3 the coefficient associated to cash ratio is negative and significant lending more support to a substitution effect between accounts payable and cash.

In Table 3.1, the coefficient of inventories ratio is positive in both the simulated and the empirical samples. The coefficient on inventories ratio in Columns 3 and 4 becomes lower compared to the standard POLS estimate in Column 2. The availability of collateral for trade credit changes dramatically across industries because of the different composition and characteristics of inventories. Once we control for fixed-effects the relation between inventories and accounts payable becomes slightly weaker because inventories capture some of the between industry variability. Industrial fixed effects are important to explain the behavior of trade credit as pointed out in Ng, Smith, and Smith (1999). Indeed, I find an higher adjusted R^2 for estimates in Column 4. These findings are also in agreement with Mian and Smith (1992) and Petersen and Rajan (1997) whose empirical evidence supports the link between inventories and trade credit.

Firms with more inventories obtain more funding because of the liquidation advantage of the supplier that can resell inputs through his or her selling channels at default. When default does not occur the liquidation of inventories by the firm increases the costs related to trade credit. To test the magnitude of inventories liquidation costs, I simulated the same model described above without liquidation costs due to obligations accounts payable. In the that case, the estimated coefficient on inventories ratio becomes even larger as expected. Availability of collateral is a crucial condition for demanding trade credit also for large firms as Fabbri and Menichini (2010) explain. Indeed, after controlling for size I still find a positive effect of inventories ratio on accounts payable.

In agreement with the bulk of the literature on trade credit I find that larger firms demand less credit to suppliers. Moreover, financially constrained firms are typically small firms that find very helpful credit extension from suppliers. In the empirical estimates I controlled also for other variables like sale growth and leverage. Sales growth positively impacts accounts payable. This result is explained in Petersen and Rajan (1997) with the fact that even financially constrained firms are able to obtain trade credit if they are in a period of growth. Suppliers are eager to provide credit to growth firms even if they are experiencing temporary shortage of liquidity. Finally, leverage is negatively related to accounts payable. This result is in agreement with Petersen and Rajan (1997) where it is found that firms with availability of unused credit lines and with more access to traditional credit, from banks for example, demand less trade credit.

In summary, accounts payable are an important source of flexible financing especially for financially constrained firms. This benefit, however, does not come without costs since the amount of trade debt that can be asked is bounded by the collateral requirements and by the liquidation costs due to obligations in the trade credit contract. Given liquidation costs related to trade credit cash holdings provide a better solution to manage cash flow risk and to provide the necessary funds to cover obligations from trade credit. On the other hand, small firms with good growth opportunities may find trade credit very useful since they have a sharper need of funds to finance investments. In general, except for financially constrained firms, the overall contribute to firm value of trade credit is very small. The incremental contribution of accounts payable to enterprise value, 0.65% on average, is shown in Figure 3.1. However, in bad states of the business (low values of z) trade credit is a valuable financing option. In those states, in which the firm has low or even negative cash flows, trade credit contributes to enterprise value as much as 4-5%.

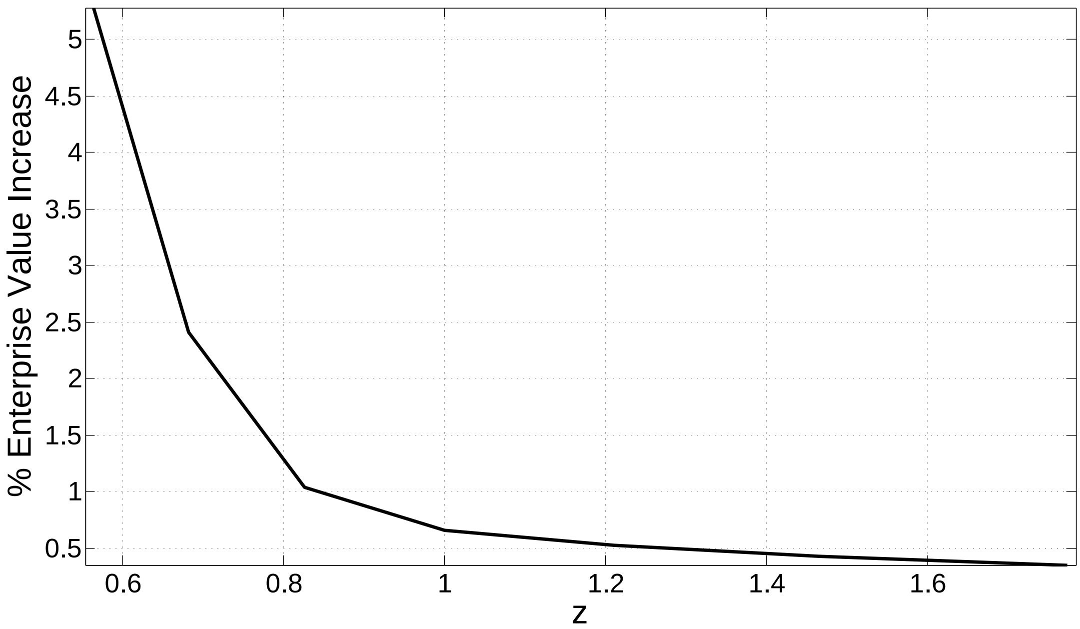


Figure 3.1. The Incremental Contribution to Firm Value of Accounts Payable. In this table I show the marginal contribution of accounts payable to enterprise value. Value increase is shown for unconditional averages of capital, inventories, cash holdings and accounts payable. Enterprise value is firm value less cash stock.

Conclusion

In this thesis I have examined the role of inventories as a risk management tool. Internally generated funds are shocked by many risk factors and negative operating cash flows generate the need for costly external finance. Inventories help to mitigate shocks to cash flows thereby reducing the likelihood of recurring to external finance.

Inventories are a source of operating and financial flexibility. Firms holding inventories can mitigate the impact of production disruptions or input supply shocks. In the first case, the firm relying on output inventories continue to satisfy demand when the firm is not able to produce or simply managers do not want to switch on production. On the input side, the negative effects of supply chain shock can be faced can be curbed with input inventories. Firms holding inventories obtain also a source of financial flexibility. Inventories are typically easy reversible with liquidation costs lower than capital liquidation costs. This creates a benefit for firms that for example have low cash stocks and have good investment opportunities. In this case, firms avoid tapping financial markets and finance investment by liquidating inventories.

Of course, inventories are not the only tool that provide flexibility. Hedging with derivatives and management of cash are two traditional risk management tools to deal with shocks to internal funds. However, derivatives only cover price risk leaving many operating risks unhedged like quantity or quality risks in the input supply. In addition, recent studies like Rampini and Viswanathan (2010) and Gamba and Triantis (2014) have emphasized the costs associated to hedging with derivatives mainly related to the counterparty risk born by counterpart of the firm in a future contract. Another cost of hedging with derivatives is the possibility for the firm to liquidate assets if internally generated funds are not enough to cover payments in the contract. All these costs deeply impact the hedging performance of derivatives suggesting to firms the use of alternative hedging strategies.

In alternative to hedging with derivatives the firm may choose to hold cash to face negative fluctuations of internal funds. Also cash implies costs like the tax penalty incurred by shareholders when managers decide to retain cash in the firm or agency costs. Another cost of holding is the opportunity cost of investing in more remunerative assets. All these costs must be counterbalanced against the future avoidance of costs of external finance.

I embedded all these features of inventories management, hedging with derivatives and management of cash in dynamic model that I solved by means of the dynamic programming approach. The results indicate a significant contribution of inventories to firm value around 5.60% under base case parameters. My results suggest that the contribution to risk management of inventories mainly derives from flexibility of substitution with other production factors. In contrast, I found scarce evidence in support of inventories as reserve of liquidity. The percentage value increase given by the dynamic management of inventories is crucially moderated by operating leverage and the degree of complementarity between capital and inventories. As explained in Ramey (1989), inventories provide higher benefits to firms with higher operating fixed costs. Accordingly, I find that the contribution of inventories to firm value is very much reduced when fixed operating costs are low. Secondly, increasing complementarity between capital and inventories reduces firm value but at the same time increases the contribution of inventories to value because they cannot be easily substituted in the production process.

Derivatives contribute less to firm value than inventories. This result hold under different parameters settings except in the case in which the cash flow is highly correlated with the underlying asset in the derivative contract. In this case, the firm may even decide to hedge with futures forgoing the possibility to manage inventories because of the very good performance of the derivative. However, it also true that perfect correlation between cash flow and derivative's underlying asset is very hard to find in reality. Cash holdings have a positive impact to firm value, 5% on average under base case parameters. Indeed, cash allows the firm to avoid external finance costs more cheaply than inventories given that inventories, even if more liquid than fixed assets, are nevertheless exposed to liquidation costs. Moreover, substitution flexibility provided by inventories is state-contingent while cash can be hold independently of the state of cash flow. However, opportunity costs heavily bound the benefit provided by cash holdings thereby leaving space for inventories that provide an higher return than cash.

The substitution effect between inventories and cash documented in Bates, Kahle, and Stulz (2009), among other important operating factors, can be explained also under a risk management perspective. According to the precautionary theory for holding cash, higher cash flow volatility leads firms to increase cash holdings. With higher cash flow volatility firms are also willing to hold more inventories thanks to their high reversibility. However, according to my results the increase in cash holding due to higher cash flow volatility is much higher than the increase in inventories. This results indicate that in a very volatile business environment the benefit provided by cash in terms of liquidity is higher than the benefit from inventories, given the presence of liquidation costs also for inventories. In addition to my theoretical study, I developed an empirical estimation of the relationship between the inventories ratio and cash ratio in sample of U.S. firms in the same period analyzed by Bates, Kahle, and Stulz (2009) between 1980 and 2006. My empirical results, robust across different estimators, confirm a strong substitution effect between inventories and cash at both the operating and risk management levels. I also empirically tested the role of inventories as a reserve of liquidity by measuring the sensitivity of inventories investment to cash flow. I found evidence on the scarce performance of inventories as reserve of liquidity and I provided further evidence on the weakness of cash flow sensitivities as measures of financial constraints, also in the case of inventories investment.

As an extension of my study of inventories, I studied the relationship between accounts payable, inventories and cash. My theoretical results confirm what it is found empirically in the literature. First of all, my model generates a positive relation between inventories and accounts payable because input inventories provide collateral for trade credit. Empirically, I found evidence in support of this prediction and in support of the explanatory power of industry fixed effects with respect to trade credit. Secondly, I theoretically found a positive relation also between accounts payable and cash, that, however, is not confirmed in the data. With this study on trade credit, I pointed out another benefit of inventories related to their role as collateral for short-term trade financing.

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Appendix

Proof of Propositions

Proofs are presented only for the model with hedging with derivatives but can be easily extended to the model with cash holdings. The solution of the Bellman equation (B) exists, it is continuous and it coincides with the unique maximum attained solving (SP) because the following conditions hold (Stokey and Lucas (1989), Ch.9, Ass. 9.4-9.7 and Th. 9.6):

1. the set of endogenous state variables, A_{zx}, is a compact and convex Borel set in $\mathbb{R}^3$ for all $(z, x) \in S$;

2. A_{knh} is a compact and convex Borel set for all $(k, n, h) \in U$ and $\mu(s,\, ds')$ has the *Feller Property*;

3. the correspondence $\Gamma : U \times S \to U$ is non-empty, compact-valued and continuous;

4. the return function $cf : A \to \mathbf{R}$ is bounded and continuous and the discount factor satisfies $0 < \beta < 1$.

$\Gamma(u, s)$ is non-empty, compact-valued and continuous because all variables take value in continuous compact sets. $e(u, u', s)$ is bounded because it is a continuous function on a compact set.

(B) has a unique solution v^* corresponding to the unique-point of the operator $T : C(A) \to C(A)$ defined on the space $C(A)$ of bounded and continuous functions:

$$(Tv)(u, s) \;=\; \max_{u' \in \Gamma(u,s)} \left\{ e(u, u', s) + \beta \int_{S'} v(u', s')\, \mu(s,\, ds') \right\}. \tag{3.7}$$

Moreover, the following correspondence defining the optimal policy,

$$G(u, s) = \left\{ u' \in \Gamma(u, s) : v(u, s) = e(u, u', s) + \beta \int v(u', s') \mu(s,\, ds') \right\}, \tag{3.8}$$

is non-empty and compact-valued.

The firm value function is monotonically increasing in k, n and h because the first derivatives of the payout function $e(u, u', s)$ with respect to k, n and h are positive on the set A_{zx} for all $(z, x) \in S$ and because the feasible set $\Gamma(u, s)$ is increasing (Stokey and Lucas (1989), Ch.9, Th.9.7). The first derivatives of the cash flow function with respect to k and n are both positive in the set $\mathcal{K} \times \mathcal{N}$ where $f_k > (1 + \delta_k)$ and $f_n > (1 + \delta_n)$ are both satisfied. The first derivative of cash flow with respect to h is the payoff of the put option which is always non-negative. The feasible set is increasing in the sense that for a set $A' \geq A$ follows that $\Gamma(A') \geq \Gamma(A)$.

The firm value function is also strictly concave and the optimal policy function, $G(\cdot, s)$, is unique and continuous since $e(u, u', s)$ is concave in u and the feasible set A_{zx} is convex for all $(z, x) \in S$ (Stokey and Lucas (1989), Ch.9, Th.9.8). The Hessian matrix of $e(u, u', s)$ is negative definite. The payout function is concave because second order derivatives with respect to h are all zero and we know that the cash flow is concave in both k and n by construction.

Numerical Algorithm

To find k_u we start by initializing the domain of two consecutive periods cash flows for the part dependent on k and n, say, $z[\alpha k^{-\nu} + (1 - \alpha)n^{-\nu}]^{-\frac{1}{\nu}} - \delta_k k - \delta_n n$. The intervals for k and n are $[0, \bar{k}]$ and $[0, \bar{n}]$ where $\bar{k}$ and $\bar{n}$ are chosen large enough (the procedure is robust to even larger upper bounds) and the interval for z is the same used for computing firm value. Secondly, we compute the intertemporal cash flow in the domain $[z_l, z_u] \times [0, \bar{k}] \times [0, \bar{n}]$ and we find the value z^* (along with the values k^* and n^*) for which the intertemporal cash flow is maximized. Thirdly, we find k_u^j for each $n_j \in [0, \bar{n}]$ by solving $z^*[\alpha k_u^{-\nu} + (1 - \alpha)n_j^{-\nu}]^{-\frac{1}{\nu}} - \delta_k k_u - \delta_n n_j = 0$. This procedure implicitly defines a function $g(n) \to k$ that associates a value $k_u \in [0, \bar{k}]$ to each value in $[0, \bar{n}]$. Given the properties of the production function, $g(n)$ is strictly concave in n so we take the maximum value as our k_u. The same procedure is applied to find n_u.