

Dynamic Risk Management*

Adriano A. Rampini
Duke University

Amir Sufi
University of Chicago

S. Viswanathan
Duke University

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Abstract

There is a trade-off between financing and risk management as both involve promises to pay which need to be collateralized. This trade-off explains that risk management is limited and often absent and that more financially constrained firms engage in less risk management. We document that these predictions are consistent with the evidence using panel data for fuel price risk management by airlines. More constrained airlines hedge less both in the cross section and within airlines over time. Risk management drops substantially as airlines approach distress and recovers only slowly after airlines enter distress.

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1 Introduction

What determines the extent to which firms engage in risk management? A central insight from the theoretical literature is that firms engage in risk management because financing constraints render them effectively risk averse (see Froot, Scharfstein, and Stein (1993)). This insight has motivated a large number of empirical papers; however, the empirical findings do not support the prediction that firms more likely to face financial constraints are more likely to manage risk. To the contrary, many of the findings suggest exactly the opposite: firms that are more financially constrained engage in less risk management. Indeed, as Stulz (1996) writes with regard to this hypothesis, “[t]he actual corporate use of derivatives, however, does not seem to correspond closely to the theory.”

In this study, we theoretically and empirically challenge the notion that financial constraints and risk management should be positively correlated. We provide a model that predicts that risk management should be lower and even absent for firms that are more financially constrained. The basic theoretical insight, first identified in Rampini and Viswanathan (2010, 2011) and extended to commodity price risk management in this paper, is that collateral constraints link the availability of financing and risk management. More specifically, if firms must have sufficient collateral to cover both future payments to financiers and future payments to hedging counterparties, there is a trade-off between financing and risk management. When net worth is low and the marginal value of internal resources is high, firms optimally choose to use their limited net worth to finance investment at the expense of hedging. Consistent with our model, American Airlines, for example, notes in their 2009 10-K SEC filing that

“[a] deterioration of the Company’s financial position could negatively affect the Company’s ability to hedge fuel in the future.”

The specific model we build explicitly considers input price hedging, for example, fuel price hedging by airlines. In particular, we show that collateral constraints imply the same basic trade-off for dynamic commodity price risk management. A promise to purchase inputs in some state next period at a prespecified price which exceeds the spot price needs to be collateralized. Such promises are equivalent to fuel price state contingent claims and these promises as well as the promises to repay loans count against collateral constraints. The basic trade-off arises because when firms’ current net worth is sufficiently low, the financing needs for investment override the hedging concerns. Firms pledge as much as possible to finance investment, leaving no room for risk management.

We examine the empirical predictions of the model by analyzing jet fuel price hedging by U.S. airlines. This empirical setting is ideal for a number of reasons. First, jet

fuel expenses represent a very large component of overall operating expenses for airlines – in our sample jet fuel prices represent on average 20% of total operating expenses. Airlines regularly state in their financial disclosures that the cost of jet fuel is a major input cost and a key source of cash flow risk. Further, there are a number of financial instruments that allow airlines to hedge jet fuel price risk. In addition, most airlines disclose the fraction of next year’s expected fuel expenses that they have hedged in their 10-K SEC filings, which gives us unusually detailed panel data on risk management. Finally, by focusing on the airline industry as an empirical laboratory, we hold constant other characteristics of the economic environment that might vary across industries.

The discussion of fuel hedging by airlines in their 10-K SEC filings reveals a very close connection between collateral considerations and risk management decisions. For example, Southwest Airlines in their 2010 10-K SEC filing explicitly states that their jet fuel price hedges are collateralized with owned aircraft, which is exactly the mechanism linking collateral, financing, and hedging in our model. JetBlue Airways lists collateral requirements on fuel price derivatives as having an adverse effect on their liquidity. These discussions by managers in the SEC filings reveal a tight link between collateral requirements and risk management decisions, which is ignored in the extant literature on risk management.

Our empirical analysis is based on hand collected data on jet fuel price hedging from 10-K SEC filings. Our data set covers 23 U.S. airlines from 1996 through 2009 for a total sample of 270 airline-year observations. We supplement the hedging data with information from Capital IQ and S&P’s Compustat. The panel structure of the data allows us to exploit both cross-sectional and within-airline variation to assess the correlation between measures of net worth and risk management.

We first show that almost no airline completely hedges its jet fuel price risk and that hedging is completely absent for a large number of airlines. The only airlines that hedge more than 60% of their expected jet fuel expenses are small airlines that utilize fuel pass through agreements, which are agreements where a major carrier sells fuel to the smaller airline and bears the jet fuel price risk. Among the majority of airlines without fuel pass through agreements, 30% of the airline-year observations involve no hedging and the average hedging is only 23% of expected jet fuel expenses. What is most notable about risk management is its absence.

Using several measures of net worth, we then show a very strong positive cross-sectional correlation between net worth and the fraction of next year’s fuel expenses hedged. Using airline averages over the entire sample, we find that airlines with higher net worth (either in levels or scaled by total assets), higher cash flow, and higher credit

ratings hedge more of their expected fuel expenses. In terms of magnitudes, a one standard deviation increase in the market value of net worth scaled by the market value of the firm is associated with a one-half standard deviation increase in the fraction of next year's fuel expenses hedged.

The strong positive correlation between measures of net worth and hedging also holds within airlines over time. Using airline fixed effects regressions, we show that within-airline variation in measures of net worth are strongly positively correlated with the fraction of fuel expenses hedged. We also use a first difference specification, which is perhaps the most stringent test of the correlation. We find that an increase in net worth from last year to this year for a given airline is associated with an increase in the fraction of next year's fuel expenses hedged. The magnitude of the correlation is similar across the cross-sectional, fixed effects, and first difference specifications.

Furthermore, we examine 10 situations in which airlines experience distress, which we define as being rated CCC+ or worse, or, for unrated airlines, being in bankruptcy. From two years before to the year before entering distress, hedging of expected fuel expenses declines slightly from about 30% to about 25%. From the year before distress to the year entering distress, hedging plummets from about 25% to less than 5% of expected fuel expenses. In the two years after, hedging partially recovers, rising back to almost 20%.

To further understand the reasons why fuel price hedging drops so dramatically in distress, we read all mentions of hedging by these airlines in their 10-K SEC filings. The fraction of airlines mentioning collateral considerations or their financial position as limiting their ability to hedge rises from 0% two years before to 70% in the year of distress. Firms entering distress state that they are reducing hedging because of collateral considerations and a weak financial position, exactly the mechanism of our model.

We conduct several robustness tests that confirm the strong positive relation between net worth and hedging. Our results are materially unchanged when we exclude firms in distress, when we focus on subperiods when oil prices fall or rise, when we exclude Southwest Airlines, when we exclude airlines with fuel pass through agreements, and when we adjust assets for leased capital. We also address the alternative hypothesis that firms with lower net worth hedge less because of risk shifting, and we provide evidence that this is not the case in our sample.

The paper proceeds as follows. Section 2 discusses the current state of the empirical and theoretical literature on risk management. Section 3 provides the model and characterizes the empirical predictions of our dynamic theory of commodity price risk management. Section 4 describes our data on fuel price risk management by airlines and provides anecdotal evidence regarding the trade-off between financing and risk manage-

ment from the airline industry. Section 5 tests our theory and Section 6 provides evidence on fuel price hedging by airlines in and around distress. Section 7 provides various robustness tests and discusses alternative hypotheses and policy implications. Section 8 concludes.

2 Risk management: State of the literature

Much of the extant empirical literature on risk management has been guided by the theoretical insights of Froot, Scharfstein, and Stein (1993). One of their central findings is that “if external funds are more costly to corporations than internally generated funds, there will typically be a benefit to hedging.” The empirical literature following their work has interpreted this finding to imply a positive relation between measures of financial constraints and risk management activity. In other words, if a firm is more financially constrained, it should typically have more of a need for hedging. For example, in his noted empirical study of risk management, Tufano (1996) writes that

“... theory predicts an inverse relationship between firm size and delta-percentage; smaller mines might engage in greater risk management so as to avoid having to seek costly external financing.”

However, the empirical literature has found precisely the opposite relation in a variety of settings. For example, Nance, Smith, and Smithson (1993) find that firms which do not hedge are smaller and pay lower dividends in survey data for large industrial firms. Similarly, Géczy, Minton, and Schrand (1997) find a strong positive relation between derivatives use and firm size among large U.S. firms.¹ Many researchers have commented on the tension between the theory and the practice of risk management by corporations. As briefly mentioned above, Stulz (1996) writes that

“[t]he actual corporate use of derivatives, however, does not seem to correspond closely to the theory. For one thing, large companies make far greater use of derivatives than small firms, even though small firms have more volatile cash flows, more restricted access to capital, and thus presumably more reason to buy protection against financial trouble.”

Even Froot, Scharfstein, and Stein (1993) note this tension:

¹They find that approximately 41% of the firms with exposure to foreign currency risk in their data use currency derivatives and 59% use any type of derivative; across firm size quartiles, currency derivative use increases from 17% for the smallest quartile to 75% for the largest quartile and the use of any derivatives increases from 33% to 90%.

“[Nance, Smith, and Smithson (1993)] find that high-dividend-paying firms are more likely to hedge. It is not obvious how this fact squares with our model. ... [They] also find that smaller firms are less likely to hedge. This fact is generally inconsistent with our model if one believes that smaller firms are more likely to be liquidity constrained ...”

Moreover, in the context of jet fuel price hedging by airlines, Carter, Rogers, and Simkins (2006a, 2006b), who focus on the effect of hedging on firm value, find that “the most active hedgers of fuel costs among airlines are the larger firms with the least debt and highest credit ratings.” But given the perceived tension with theory, they go on to say that “[t]his result is somewhat surprising ...”²

The empirical literature on corporate risk management more broadly includes the noted industry study of gold mining firms by Tufano (1996). His study, like ours, uses detailed data for one particular industry to understand risk management. The firms in his study hedge an output price whereas the airlines in our sample hedge the cost of a major input, jet fuel. Moreover, Tufano has data for only 3 years, albeit at a quarterly frequency, and his data is hence effectively cross sectional, whereas we have panel data with (up to) 15 years of data. Tufano finds limited support for extant theories and focuses instead on the effect of managerial compensation and manager characteristics on risk management. We find a rather strong relation between firms’ financial condition and risk management as predicted by our theory and focus our empirical work squarely on this relation.

In contrast to our work and Tufano’s study, other empirical studies typically use categorical data, that is, indicator variables taking a value of one for firms that use derivatives and zero otherwise and a single cross section. While the evidence on the relation between corporate risk management and various financial variables is somewhat mixed in such cross-sectional studies, the two relatively robust patterns that emerge are consistent with our empirical results: First, there is a positive relation between hedging and firm size; and second, there is a positive relation between hedging and firms’ dividend yield (see, for example, Mian (1996) in addition to the papers mentioned above). Graham and Rogers (2002) find no evidence that firms hedge in response to tax convexity. Guay and Kothari (2003) find that risk management is quantitatively small even for large firms and argue that the use of categorical data may hence give a misleading picture of the extent of risk management in practice. Our empirical work uses detailed panel data on the intensive margin of risk management for the airline industry, in which risk management is quantitatively important.

²Morrell and Swan (2006) and Morrell (2007) observe that most large airlines engage in some amount of risk management and emphasize the role of financial constraints in limiting risk management.

Previous work does at times tangentially note the positive relation between hedging and size and between hedging and dividend yields; however, it is important to recognize that this relation has not been carefully documented nor has it been explored in detail before. This may seem surprising since the correlation we find is so remarkably strong and positive. One reason is that previous studies typically do not use panel data on the intensive margin. Another reason is that researchers perceive this positive correlation as contradicting received theory making them reluctant to explore it further – that is, a case of theory holding back empirical work (see, for example, the quote from Carter, Rogers, and Simkins above). In any case, we are the first to document and carefully investigate the strong positive correlation between hedging and net worth.

The theoretical literature includes several studies of the link between financial constraints and corporate risk management.³ The rationale for corporate risk management in our paper is the effective risk aversion of firms subject to financial constraints, which is also the motivation for risk management in Froot, Scharfstein, and Stein (1993). In their model, however, hedging occurs in frictionless markets, and is not subject to collateral constraints, and there is no investment in the period in which firms hedge. Thus, there is no trade-off between financing and risk management in their model. Holmström and Tirole (2000) note that credit constrained entrepreneurs may choose not to buy full insurance against liquidity shocks, which is related to our result that incomplete risk management is optimal. Mello and Parsons (2000) also argue that financial constraints may constrain hedging. These papers do not provide a fully dynamic analysis of the trade-off between financing of investment and risk management. Rampini and Viswanathan (2010, 2011) study this trade-off in a similar environment but do not consider commodity price risk management.⁴

³The related literature on dynamic firm financing is discussed in Rampini and Viswanathan (2011).

⁴The theoretical literature also provides several other explanations for risk management, including tax smoothing in the presence of convex tax schedules and a reduction in expected bankruptcy costs which allows higher leverage (see, for example, Mayers and Smith (1982) and Smith and Stulz (1985)), managerial risk aversion (see, for example, Stulz (1984)), and information asymmetries between managers and shareholders (DeMarzo and Duffie (1995) and Breeden and Viswanathan (1998)). Leland (1998) interprets risk shifting in his model as a reduction in (otherwise costless) risk management; that is, a lack of risk management is a reflection of a bondholder shareholder conflict. This type of agency problem however implies that distressed firms should engage in speculative trading. We find no evidence of such activities, nor are we aware of other empirical evidence consistent with this prediction. In contrast, in our model firms limit risk management because of its opportunity cost induced by collateral constraints.

3 Dynamic risk management

We provide a dynamic model of firm financing and risk management in which firms need to collateralize all promises. Firms' financial constraints are the motive for risk management. In the model, firms are subject to commodity price risk for an input used in production as well as productivity risk,⁵ and choose their investment, financing, and risk management policies given collateral constraints. The model predicts a fundamental trade-off between financing and risk management: more constrained firms should engage in less risk management, both in the cross section and the time series.

3.1 Environment

Time is discrete and the horizon is infinite. The firm is risk neutral, subject to limited liability, and discounts payoffs at rate $\beta \in (0, 1)$. We write the firm's problem recursively and denote variables measurable with respect to next period with a prime. The firm has access to a standard neoclassical production function with decreasing returns to scale. Production requires capital k as well as an input good x' . An amount of capital k and inputs x' produce output $\hat{A}'k^{\hat{\alpha}}x'^{\phi}$ where $\hat{\alpha} > 0$, $\phi > 0$, and $\hat{\alpha} + \phi < 1$. Capital depreciates at rate $\delta \in (0, 1)$ and inputs are used up in production. The input has an exogenous price p' which is stochastic. The price of capital is normalized to 1. The price of the output good is subsumed in the total factor productivity $\hat{A}' > 0$ which is stochastic. We denote the exogenous state by $s \equiv (\hat{A}', p)$ and assume that the state follows a joint Markov process where the transition probability from the current state s to state s' next period is denoted $\Pi(s, s')$.

There are risk neutral lenders who discount payoffs at rate $R < \beta^{-1}$.⁶ These lenders have deep pockets in all dates and states, and have sufficient collateral so that we can ignore any enforcement constraints for them. They are thus willing to provide any state contingent claim or forward purchase contract on the input at an expected return R .

The firm maximizes the expected discounted present value of dividends, given its current net worth w and the current exogenous state s by choosing the current dividend d , capital k , state-contingent borrowing b' , and state-contingent forward purchases of inputs in the amount of x'_f at forward price p'_f instead of the spot price p' for all states s' next period. The price of a claim which delivers one unit of the input at price p'_f in state s'

⁵Productivity risk can for example be interpreted as a stochastic price of the output produced. Moreover, the model can be easily adapted to handle other types of risk, such as cash flow risk due currency risk and interest rate risk.

⁶This assumption ensures that firm financing matters even in the long run.

when the spot price is p' is $R^{-1}\Pi(s, s')(p' - p'_f)$ up front. The price of such a claim can be positive or negative depending on whether the forward price p'_f is below or above the spot price p' . If p'_f exceeds p' , this amounts to a promise to purchase a unit of input above the spot price, and such promises have to be collateralized.

Specifically, enforcement is limited as follows. Firms can abscond with all cash flows and fraction $1 - \theta$ of capital and cannot be excluded from the spot market for inputs and the market for loans. Importantly, firms can purchase (or sell) any amount of input in the spot market at any time. This implies that firms have to collateralize all promises and these cannot exceed fraction θ of the resale value of (depreciated) capital. In particular, firms have to collateralize promises to repay loans Rb' and thus such promises count against the collateral constraint. Furthermore, firms have to collateralize promises associated with forward purchases of inputs. When firms default and do not take delivery of the inputs agreed to under the forward purchase at the prespecified price, the counterparty keeps the inputs x'_f and thus it is the net promises $(p' - p'_f)x'_f$ that count against the collateral constraint.

3.2 Commodity price risk management

Consider first the static profit maximization problem of the firm, taking the amount of capital k as given. By maximizing output net of the cost of the additional input, we can solve for the demand function for the input x' as a function of k and p' and determine the profit function.

Proposition 1 *The profit function can be written as $A'k^\alpha$ where the effective productivity A' depends on the state, that is, both productivity \widehat{A}' and commodity prices p' : $A' \equiv \widehat{A}'^{\frac{1}{1-\phi}}(1 - \phi)\phi^{\frac{\phi}{1-\phi}}p'^{-\frac{\phi}{1-\phi}}$ and $\alpha = \widehat{\alpha}/(1 - \phi)$.*

Note that the profit function is convex in the price of the input p' , as is of course well known. But firms nevertheless have an incentive to hedge input price risk. The intuition is that a high input price is equivalent to a negative productivity shock and thus reduces the firm's profits and net worth. In order to ensure sufficient net worth, the firm may hence want to hedge states in which the input price is high.

We now argue that hedging commodity price risk is equivalent to hedging net worth. For suppose a firm enters into a forward contract to purchase a specific amount of the input at a prespecified forward price in some state next period. If the forward price is lower than the spot price in that state, such a transaction simply amounts to shifting net worth in the amount of the price difference times the amount of input goods underlying

the contract into that state.⁷ Analogously, if the forward price is higher than the spot price, the transaction shifts net worth out of that state. Moreover, in that case the forward contract amounts to a promise to pay the amount corresponding to the price difference times the amount of input goods underlying the contract to the counterparty of the forward. But such a promise is only credible if it is collateralized. We summarize this insight in the following proposition:

Proposition 2 *Since the promises to pay associated with forward purchases need be collateralized as do the state-contingent loan payments Rb' , firm financing and risk management are subject to the collateral constraints*

$$\theta k(1 - \delta) \geq Rb' + (p'_f - p')x'_f.$$

State-contingent one-period ahead forward purchases of the input (in state s') in the amount x'_f at forward price p'_f are equivalent to one-period ahead commodity price contingent claims where

$$h'_p \equiv (p' - p'_f)x'_f.$$

Defining the state-contingent claims $h'_w \equiv \theta k(1 - \delta) - Rb'$ and denoting the overall portfolio of state-contingent claims $h' \equiv h'_w + h'_p$, the collateral constraints above are equivalent to noncontingent borrowing $\varphi \equiv 1 - R^{-1}\theta(1 - \delta)$ per unit of capital and hedging h' subject to short-sale constraints $h' \geq 0$.

Using Propositions 1 and 2 the firm's problem can now be formulated recursively. Given the firm's net worth w , the firm chooses the current dividend d , capital k , (state-contingent) net worth w' , and state-contingent claims h' to maximize the expected discounted value of dividends. Note that Proposition 2 allows us to substitute noncontingent debt and state-contingent claims h' for state-contingent borrowing b' and commodity-price contingent claims h'_p . This equivalent formulation amounts to assuming that the firm borrows as much as it can against each unit of capital, that is, borrows a state-noncontingent amount $R^{-1}\theta(1 - \delta)$ and pays down only $\varphi \equiv 1 - R^{-1}\theta(1 - \delta)$ (using internal funds) per unit of capital. The firm purchases an overall portfolio of Arrow securities h' which are the sum of h'_w and h'_p . The firm purchases state-contingent claims h'_w to the extent that it does not borrow the maximal amount in the formulation with state-contingent debt. The firm moreover hedges commodity price risk using the commodity-price contingent claims h'_p . Such hedging simply affects the firm's net worth in state s' next period, not

⁷Critically, the quantity underlying the forward contract may differ from the amount of input goods actually used in production. The firm can always purchase additional amounts of inputs or sell excess inputs in the spot market. The static production decision is separable from the hedging policy.

its production decision. Effectively, we assume perfect enforcement in the spot market for the input good whereas intertemporal promises need to be collateralized.

Our model allows a simple recursive formulation of the firm's dynamic financing and risk-management problem:

$$V(w, s) \equiv \max_{\{d, k, w', h'\} \in \mathbb{R}_+^{2+S} \times \mathbb{R}^S} d + \beta E[V(w', s')|s] \quad (1)$$

subject to the budget constraints for the current period and each state next period,

$$w \geq d + \wp k + R^{-1} E[h'|s] \quad (2)$$

$$A'k^\alpha + (1 - \theta)k(1 - \delta) + h' \geq w', \quad (3)$$

and the short sale constraints

$$h' \geq 0. \quad (4)$$

The budget constraint for the current period (2) states that current net worth can be spent on the current dividend d , down payments for capital $\wp k$ for the next period, and a portfolio of contingent claims to hedge risk for the next period worth $R^{-1} E[h'|s]$. The budget constraints for next period (3) state that, for each state s' next period, profits from production using the optimal amount of the input good $A'f(k)$, the resale value of capital $k(1 - \delta)$, and the payoffs of the contingent claims h' determine the firm's net worth w' going forward. Note that this program requires that dividends d , capital k , and net worth w' are non-negative. Let $z \equiv (d, k, w', h')$ and define the set $\Gamma(w, s)$ be the set of $z \in \mathbb{R}_+^{2+S} \times \mathbb{R}^S$ such that (2) through (4) are satisfied. Note that the set $\Gamma(w, s)$ is convex. Thus the problem is well-defined and, using standard arguments, there exists a unique value function that solves the fixed point problem. This value function is strictly increasing in net worth w and concave in w . Indeed, the value function is strictly concave in net worth below a state-contingent dividend threshold $\bar{w}(s)$, $\forall s \in S$. Our model of commodity price risk management thus maps into the environment with productivity shocks only studied by Rampini and Viswanathan (2011) and we defer to that paper for explicit proofs unless otherwise stated.

The concavity of the value function that solves the firm's problem in (1) through (4) is of course the motivation for risk management. Indeed, the firm acts as if it were risk averse with respect to net worth despite the fact that it is risk neutral. Further, while the effective productivity A' is convex in the commodity price, risk management does not affect the spot price of the commodity itself. Instead, the spot price of the commodity determines the effective productivity and firm net worth, while commodity price risk management shifts net worth across states with different effective productivity and cash flows, about which the firm is risk averse.

If commodity prices span uncertainty, then commodity price risk management alone suffices, that is, we can set $h' = h'_p$ (and $h'_w = 0$) without loss of generality. The simplest case of this is the case in which commodity prices are the only source of uncertainty. Furthermore, long-term commodity price contingent claims are redundant as these can be replicated dynamically despite short sale constraints. Thus, the absence of risk management using long-term commodity derivatives may not be a consequence of the absence of markets for such claims but rather due to the fact that dynamic replication works even in the presence of collateral constraints in our model. Importantly, long-term claims do not expand the space of credible promises. In fact, complete markets in one-period ahead Arrow securities h' are sufficient for the implementation of optimal risk management. In other words, markets for long-term contingent claims are redundant despite the presence of short-sale constraints. The absence of corporate hedging at longer horizons can thus be interpreted simply as a reflection of two facts: first, financing constraints limit risk management and second, risk management can be implemented by dynamic trading in one-period claims even in the presence of collateral constraints. This explanation contrasts with the usual argument that depends on the absence of long horizon derivatives markets.

The above analysis reflects currency price risk management as follows. If the input good is denoted in a different currency, then currency risk is equivalent to a stochastic input price p' . If the output good (or part thereof) is denoted in a different currency, the currency price risk is equivalent to a stochastic productivity \hat{A}' . Thus, currency risk is an important application of our environment.⁸

3.3 The financing risk management trade-off

Our theory has two important implications. First, firms engage only in limited risk management; indeed, the most striking observation about risk management is its absence. Second, firms which are more financially constrained engage in less risk management, that is, there is an important link between firm financing and risk management. These implications are consistent with basic stylized empirical patterns reported in the literature and with the detailed evidence on risk management by airlines that we provide.

Our basic result about the absence of risk management is the following:

Proposition 3 (No risk management by severely constrained firms) *Firms which*

⁸We can study interest rate risk management by simply assuming that the interest rate R in problem (1) through (4) is stochastic but known at the beginning of the period, that is, $R(s)$ and $\varphi(s) \equiv 1 - R(s)^{-1}\theta(1 - \delta)$ depend on the state $s \in S$. The above analysis applies without change.

are severely financially constrained, that is, firms with sufficiently low net worth, do not engage in commodity price risk management.

Since this is the crucial result we prove it in the text.⁹ Using the first order conditions for the firm's problem in equations (1) through (4) and the envelope condition, we obtain the (conditional) Euler equation for investment

$$1 = E \left[\beta \frac{V'_w}{V_w} \frac{A' \alpha k^{\alpha-1} + (1-\theta)(1-\delta)}{\varphi} \middle| s \right], \quad (5)$$

where $V_w \equiv V_w(w, s)$ ($V'_w \equiv V'_w(w', s')$) is the derivative of the value function this (next) period with respect to w (w'). The firm's stochastic discount factor $\beta V'_w/V_w$ is not just β despite the assumption of risk neutrality since the firm's value function V is concave. This is the effective risk aversion induced by financial constraints. As the firm's net worth w goes to zero, the firm's capital stock k has to go to zero as well, since the budget constraint implies that $w \geq \varphi k$. But then the marginal product of capital goes to $+\infty$, for all $s' \in S$, and using the investment Euler equation (5) and dropping terms we have

$$1 \geq \Pi(s, s') \beta \frac{V'_w}{V_w} \frac{A' \alpha k^{\alpha-1} + (1-\theta)(1-\delta)}{\varphi},$$

which implies that $\beta V'_w/V_w$ goes to zero, $\forall s' \in S$.

The first order condition for risk management h' , together with the envelope condition, implies

$$R^{-1} \geq \beta \frac{V'_w}{V_w},$$

and $h' = 0$ if the inequality is strict for state s' . But by above as the firm's net worth goes to zero, the right hand side goes to zero, and the inequality is necessarily strict; that is, $h' = 0, \forall s' \in S$. Severely constrained firms do not engage in risk management. This completes the proof of Proposition 3. Note that no assumptions about the Markov process $\Pi(s, s')$ are necessary for the result and thus the result obtains for any Markov process.

The intuition for this result, which is illustrated in Figure 1 for the case in which commodity prices follow a two state Markov process, is that the financing needs for investment override the hedging concerns when current net worth is sufficiently low. Low net worth implies that the firm is not able to purchase much capital and hence the marginal product of capital must be high. The firm thus pledges as much as it can against its capital in all states next period in order to be able to invest in as much capital as possible. As a result, the firm does not engage in risk management. Issuing promises to

⁹See also Rampini and Viswanathan (2011).

pay against high net worth states next period in order to shift net worth to low net worth states next period has an opportunity cost, as such promises are also used to finance current investment.¹⁰ Thus, collateral constraints link financing and risk management.¹¹

We henceforth assume for simplicity that the input price is the only source of uncertainty, but extending the results to include productivity risk as well is straightforward. Under the assumption that the uncertainty is independent and identically distributed over time, an asymmetric hedging policy is optimal, that is, the firm hedges all commodity prices next period above a certain threshold, if it hedges at all. Firms might optimally abstain from risk management altogether, as Proposition 3 implies. Moreover, the optimal risk management policy effectively ensures a lower bound on the firm's net worth next period.

Proposition 4 (Optimality of asymmetric risk management policy) *Suppose the Markov process of the input price p is independent, that is, $\Pi(s, s') = \Pi(s')$, for all $s, s' \in S$. (i) Firms hedge commodity prices above a certain threshold, if at all, and never hedge perfectly, that is, there are states $s', \hat{s}' \in S$ next period with different commodity prices $p' \neq \hat{p}'$ across which firms' net worth, as well as firms' marginal value of net worth, is not equalized. (ii) Firms have the same net worth across all states next period that firms hedge and higher net worth in all other states.*

To ensure that the firm's net worth does not fall below a lower bound, as Proposition 4 implies, the firm chooses an optimal risk management policy with a concave payoff.

Proposition 5 (Optimality of concave hedging payoff) *Given the assumptions of Proposition 4, the payoff of the optimal risk management policy is concave in the input price in the range where the payoff is positive and 0 otherwise.*

Intuitively, the firm's hedging policy ensures a level of net worth w'_h next period for all states it hedges. To understand this result, consider two states $s', \hat{s}' \in S$ next period with

¹⁰We emphasize that severely constrained firms with low net worth due to low cash flow realizations may be forced to downsize because of their low net worth, but choose to use their entire (limited) net worth to finance capital going forward rather than using some of it to engage in risk management.

¹¹Since our model features complete markets on the sub-space of collateralized trades and hence forwards and futures can be replicated, the financing risk management trade-off applies to forwards and futures as well, despite the fact that these instruments do not involve an up-front payment. This is because such instruments involve promises to pay in some states next period, which have opportunity costs due to the collateral constraints; these opportunity costs are determined by the financing needs in the current period and are high for severely constrained firms.

different commodity prices $p' \neq \hat{p}'$ which the firm hedges. Because the firm must have the same net worth in both states, (3) implies that

$$A(s')k^\alpha + (1 - \theta)k(1 - \delta) + h_p(s') = A(\hat{s}')k^\alpha + (1 - \theta)k(1 - \delta) + h_p(\hat{s}'),$$

that is, the sum of the payoff of the hedging policy plus the profit from operations and the resale value of the fraction of capital financed internally is constant across states that are hedged. Since profits are decreasing and convex in the input price (see Proposition 1), the payoff of the hedging policy has to be increasing and concave in the input price, which is what the proposition asserts. Such a payoff could be implemented in practice by purchasing a portfolio of call spreads.

Above we conclude that severely constrained firms may abstain from risk management. We now provide a much stronger result about the optimality of the absence of risk management. This result shows that even under the stationary distribution of firm net worth, the absence of risk management is optimal for some firms.

Proposition 6 (Absence of risk management under the stationary distribution)

Given the assumptions of Proposition 4, firms abstain from risk management with positive probability under the unique stationary distribution.

This proposition may be particularly relevant as in the data many mature firms abstain from risk management and firms discontinue risk management if their financial condition deteriorates sufficiently. Proposition 6 predicts exactly that: a sufficiently long sequence of high commodity prices and hence low profits eventually results in even mature firms getting so financially constrained, that they stop risk management.

Propositions 3 and 6 provide the key empirical predictions of our model.¹²

Prediction 1 *In the cross section, more constrained firms engage in less risk management and may not engage in risk management at all.*

Prediction 2 *In the time series, as firms' financial conditions deteriorate (improve), they reduce (increase) the extent of risk management and may stop hedging completely (may initiate risk management).*

We test these predictions using the airline industry as our empirical laboratory in the remainder of the paper.

¹²While we do not provide a general monotonicity result for the hedging policy, the numerical results in Rampini and Viswanathan (2011) show monotonic behavior independent of the level of persistence of the Markov process considered. In the model, persistence implies variation in the conditional expectation of productivity, which can be interpreted as stochastic investment opportunities, and does of course affect the extent to which various states are hedged, as emphasized by Froot, Scharfstein, and Stein (1993).

4 Airline industry as an empirical laboratory

We test the predictions of our theory by examining fuel price risk management in the airline industry. The airline industry offers an excellent laboratory for the following reasons. First, as in our model, the cost of jet fuel is a major cost for airlines, comprising on average 20% of costs and as much as 30% or more when oil prices are high. As a result, jet fuel price volatility represents a major source of cash flow risk for airlines. Second, more detailed data on the extent of risk management are available from airlines' 10-K SEC filings than for other firms. The data set is based on a hand-collected data set of U.S. airlines' Form 10-K, Item 7(A), which provides "Quantitative and Qualitative Disclosures about Market Risk." Third, focusing on one industry holds constant characteristics of the economic environment, such as the fraction of tangible capital and inputs used in production, that vary across industries.

4.1 Data on U.S. airlines

The sample we use in our analysis includes 23 airlines that we follow from 1996 to 2009 for a total sample of 270 airline-year observations. We draw our sample from S&P's Compustat. We define as an airline any company that has reported an SIC code of 4512 or 4513 on a 10-K filing from 1996 through 2009 or any company that Compustat has assigned an SIC code of 4512 or 4513 during the same time period. There are 52 airlines by this broad definition. Of these 52 companies, 13 are not commercial passenger airlines and we exclude these. Among others, these include FedEx Corp., Airborne Inc., and Air Transport Services Group.

From the remaining 39 airlines, we drop 7 airlines with average total assets below \$50 million (in 2005 dollars). These very small airlines exhibit highly variable and skewed performance. For example, the mean operating income scaled by lagged assets is -30%. We also drop 9 airlines for which we have fuel hedge data for less than 5 years. The latter restriction is due to the fact that much of our empirical analysis is focused on within-airline variation, and we want to study only airlines that remain in the sample for a sufficiently long period. Three of these 9 airlines are in the sample for only 1 year, and 8 of the 9 are in the sample for less than 4 years. After these screens, we are left with our final sample of 23 airlines.

For these airlines, we collect information on jet fuel price hedging directly from 10-K SEC filings. The availability of electronic 10-K SEC filings greatly reduces the costs of collecting the data, which is why our sample begins in 1996. The information provided by airlines with regard to their fuel hedging practice is documented carefully by Carter,

Rogers, and Simkins (2006a), and our methodology for collecting the data is similar to theirs.

For just under 90% of airline-year observations in our sample the airlines report the fraction of the following year's expected jet fuel expenses that are hedged. For three airline-year observations, the airline reports the fraction of fuel expenses hedged for each of the next four quarters; we use the average of these four quarterly numbers for these observations. For three more observations, the airline provides a nominal amount of fuel hedged, which we scale by the one year lag of fuel expenses. The results are nearly identical when removing these six observations. Airlines also report whether they have a fuel pass through agreement, which are agreements with a typically larger carrier in which the larger carrier provides jet fuel and bears the price risk. We supplement the Compustat and jet fuel expense hedging data with information from Capital IQ on jet fuel expenses.

4.2 Evidence from airlines' 10-K SEC filings

Collateral constraints are a key determinant of risk management in our model. In this subsection, we provide evidence from airlines' 10-K SEC filings that supports the assumption that collateral plays an important role in airlines' fuel hedging decisions.

A main feature of the model is that hedging requires net worth due to collateral constraints. In their 2008 10-K filing, United Airlines directly links their fuel price hedging program with the collateral required to sustain it:

“The Company utilizes various types of hedging instruments including [collars] ... If fuel prices rise above the ceiling of the collar, the Company's counterparties are required to make settlement payments to the Company, while if fuel prices fall below the floor of the collars, the Company is required to make settlement payments to its fuel hedge counterparties. In addition, the Company has been and may in the future be further required to provide counterparties with cash collateral prior to settlement of the hedge positions. ...

The price of crude oil reached a record high of approximately \$145 per barrel in July 2008 and then dramatically decreased in the second half of the year to approximately \$45 per barrel at December 31, 2008. ... While the Company's results of operations should benefit significantly from lower fuel prices on its unhedged fuel consumption, in the near term lower fuel prices could also significantly and negatively impact liquidity based on the amount of cash settlements and collateral that may be required.”

In their 2008 10-K filing, JetBlue Airways discusses how cash collateral requirements on jet fuel hedging contracts affect their liquidity:

“Under the fuel hedge contracts that we may enter into from time to time, counterparties to those contracts may require us to fund the margin associated with any loss position on the contracts if the price of crude oils falls below specified benchmarks. Meeting our obligations to fund these margin calls could adversely affect our liquidity.”

In the next year, JetBlue discloses that they are unwinding their fuel price hedging program to increase their cash holdings and to reduce collateral requirements:

“We continue to focus on maintaining adequate liquidity. ... In the fourth quarter of 2008, we effectively exited a majority of our 2009 fuel hedges then outstanding and prepaid a portion of our liability thereby limiting our exposure to additional cash collateral requirements.”

Airtran Holdings Inc. discusses the sharp drop in jet fuel prices in the second half of 2008. They emphasize that this drop led to \$70M in payments to counterparties, which adversely affected their liquidity:

“[T]he material downward spikes in fuel costs in late 2008 had an adverse impact on our cash ... because we were required to post cash as collateral related to our hedging activities ...”

Perhaps the clearest and most detailed exposition of the link between collateral and jet fuel price hedging comes from Southwest Airlines; for example, their 2010 10-K devotes an entire subsection to collateral concerns. Most notably, the airline explicitly pledges aircraft as collateral for promises to counterparties associated with their hedging activity.

“The Company ... had agreements with counterparties in which cash deposits and/or pledged aircraft are required to be posted whenever the net fair value of derivatives associated with those counterparties exceeds specific thresholds.”

Their 10-K provides details on the main counterparties, of which there are five, and both cash and aircraft collateral pledged as well as a schedule of cash and aircraft collateral requirements depending on the fair value of the derivatives associated with each counterparty. As of the end of 2010, the airline had pledged \$65 million in (net) cash collateral and \$113 million in aircraft collateral to counterparties and had agreements with two counterparties to post up to \$810 million (or about 9% of the net value of its flight equipment) in aircraft collateral. To one counterparty, the airline has contingently pledged 20

of its Boeing 737-700 aircraft as collateral in lieu of cash for up to \$400 million in net liabilities.¹³ The gross positions in fuel derivatives were substantial: the fair value of fuel derivatives that were assets was \$1.3 billion and the fair value of derivatives that were liabilities was \$1.2 billion, that is, about the amount of cash and cash equivalents held by the airline overall at the end of 2010 or more than one quarter of the airline's total current assets. The net value of fuel derivatives was \$142 million.

The liabilities involved in hedging and the cash flow implications of collateral requirements can be substantial as the airline's 2008 10-K shows: as of the end of 2008, the net fair market value of derivatives amounted to a liability of \$991 million since fuel prices dropped dramatically resulting in a drop in the fair market value of fuel derivatives of about \$1.5 billion in 2008; the airline went from holding \$2.0 billion dollars in cash as collateral posted by counterparties at the end of 2007 to itself posting \$240 million in cash as collateral at the end of 2008, which amounts to a cash outflow of \$2.2 billion in 2008, about equal to the amount of cash and cash equivalents held by the airline overall at the end of 2007 or about half of the airline's total current assets. Indeed, the above agreements to post aircraft as collateral instead of cash were struck late in 2008 in part as a response to these substantial collateral needs.

Finally, the following evidence from Southwest suggests that the purpose of airlines' derivatives positions is risk management, not speculation.¹⁴ Southwest explains the purpose of their hedging in their 2010 10-K as follows:

“Airline operators ... are impacted by changes in jet fuel prices. Furthermore, jet fuel and oil typically represents one of the largest operating expenses for airlines. ... The Company utilizes financial derivative instruments ... as a

¹³“During January 2011, the Company made the decision to forego its option under the agreement with one counterparty ... to use some of its aircraft as collateral in lieu of cash and has provided additional cash to that counterparty to meet its collateral obligation based on the fair value of its outstanding fuel derivative instruments. This decision, which can be changed at any time under the existing agreement with that counterparty, was made because the Company has an adequate amount of cash on hand available to cover its total collateral requirements and has determined it would be less costly to provide the cash instead of aircraft, due to the nominal additional charges it must pay if aircraft are utilized as collateral.”

¹⁴The airline reports being a party to over 600 financial derivative instruments related to its fuel hedging program, including crude oil, unleaded gasoline, and heating oil-based derivatives, which are primarily traded in over-the-counter markets. The airline uses these instruments “[b]ecause jet fuel is not widely traded on an organized futures exchange, [and] there are [hence] limited opportunities to hedge directly in jet fuel.” “The Company ... typically uses a mixture of purchased call options, collar structures (which include both a purchased call option and a sold put option), call spreads (which include a purchased call option and a sold call option), and fixed price swap agreements in its portfolio.”

form of insurance against the potential for significant increases in fuel prices.”

They explicitly state that

“[t]he Company does not purchase or hold any derivative financial instruments for trading purposes”

and that

“[t]he Company evaluates its hedge volumes strictly from an ‘economic’ standpoint and does not consider whether the hedges qualified or will qualify for hedge accounting.”

Southwest’s discussion of their hedging policy is consistent with the role of risk management in our model.

4.3 Summary statistics and extent of risk management

Table 1 lists the names of the airlines in our sample. The airlines are sorted by size with the largest airlines at the top. This table also lists the first and last year in the sample for each airline. In the final column of Table 1, we report whether the airline in question ever had a fuel pass through agreement, which we code as 100% hedged in almost all cases. As the last column shows, airlines with fuel pass through agreements tend to be small.

Table 2 presents summary statistics. Across airline-year observations, the average fraction of next year’s expected fuel expenses hedged is 39%. However, this average is skewed by the 23% of observations for which a fuel pass through agreement is in place. As the second row shows, the average fraction of expected fuel expenses hedged is only 20% among observations without fuel pass through agreements. Even at the 90th percentile of the distribution, only 50% of expected fuel expenses are hedged.

Table 2 also shows that fuel expenses are a large part of overall operating expenses. They are on average 20% of operating expenses and are as high as 33% during times when oil prices are high. Table 2 also presents summary statistics for measures of net worth and financial strength, including net worth, credit ratings, and operating income. All Compustat-based variables are defined in the caption of Table 2.

The top panel of Figure 2 shows more evidence on the fraction of fuel expenses hedged across airlines. The bars represent the average for each airline over the years that the airline is in the sample. Only four of the 23 airlines hedge more than 75% of their expected fuel expenses, and the majority of airlines hedge less than 50% of their expected fuel expenses. In the bottom panel, we remove airlines that have fuel pass through agreements

at some point in the sample. When we eliminate these eight airlines, Southwest Airlines is the only remaining airline hedging more than 50% of its expected fuel expenses. Further, 10 of the 17 remaining airlines hedge less than 25% of their expected fuel expenses.

Figure 3 shows the time series of both fuel prices and the fraction of fuel expenses hedged. Fuel cost per gallon fall from 1996 to 1998 before ascending from 1998 to 2000. After a brief fall during the recession, fuel prices increase substantially from 2002 until mid 2008, and fall dramatically in the second half of 2008 and early 2009. In other words, our sample covers periods over which fuel prices both increase and decrease, although the overall level increases over time. The fraction of fuel expenses hedged increases during the early part of the sample through 1999 and 2000. From then, the fraction of fuel expenses hedged remains relatively constant. In other words, even in the face of rising jet fuel prices, airlines are no more likely to hedge expected fuel expenses.

Overall, the evidence in Table 2 and Figures 2 and 3 demonstrates that hedging levels in the data are quite low. This is despite the fact that fuel prices represent a significant fraction of operating expenses and that fuel expenses, given the volatility of oil prices, represent a significant source of cash flow risk for airlines. The limited extent of risk management in the data is consistent with our theory.

4.4 Measuring net worth

A key prediction of the theory in Section 3 is that firms that have low net worth today should be less likely to hedge input costs. Further, as a given firm experiences negative shocks to net worth, the firm should become less likely to hedge. In this subsection, we discuss how we test these predictions using our data.

In particular, how should we measure the concept of current net worth in the model? The key insight from the model that we take to the data comes from Propositions 3 and 6. In an environment in which collateral constraints apply to both external finance and risk management activity, risk management will be lower when the marginal value of net worth today is very high. And the marginal value of net worth today is very high when the level of net worth today is low. The reason for this in the model is the concavity of the value function of the firm, which is induced by the concavity of the production function and the limited liability and collateral constraints. It is as if the firm is risk averse with regards to net worth, and hence the marginal value of net worth is high when net worth is low.

We use a total of six variables to empirically capture the notion of net worth in the model. The most obvious candidates are the total market value and total book value of net worth and we use these as two of our measures of net worth. The former is defined

as the market value of the airline less the book value of liabilities. The latter is the book value of shareholders' equity.

In the model, airlines all have the same production function; as a result, using total net worth is the closest analog to the model. In practice, the production function may differ across airlines which would justify scaling net worth by some notion of the scale of the airline. To better capture the potential cross-sectional differences in the scale of airlines, we also use the above measures of net worth scaled by the total assets of the airline.

We use two additional measures of net worth. The first is operating cash flow scaled by assets. The argument for this measure is that operating cash flow is an important component of net worth in the model; all else equal low cash flow implies low net worth and a higher marginal value of today's internal resources. The last measure we use is the credit rating of the airline. While credit ratings measure more than just the internal resources of the firm, a poor credit rating captures situations in which financing is particularly costly and internal resources have a high marginal value. We find consistent results across all our six measures of net worth.

5 Hedging and net worth

Our theory predicts that less constrained firms engage in more risk management. Consistent with our theory, we show in this section that there is a strong positive correlation between airlines' fuel price hedging and net worth both in the cross section and within airlines over time.

5.1 Hedging and net worth: Cross-sectional evidence

Figure 4 presents cross-sectional evidence on the correlation between measures of net worth and the fraction of fuel expenses hedged. For the cross-sectional analysis, we collapse the yearly data into airline level averages, which is equivalent to a between-regression analysis. Each airline in the scatter plots in Figure 4 is weighted by total assets, where the size of the circles reflects the size of the airline. Each scatter plot also includes a regression line where the regression is weighted by total assets of the firm.¹⁵

Across all six measures, there is a strong positive correlation between the measure of net worth and the fraction of next year's expected fuel expenses hedged. The outliers in

¹⁵All regressions in our study are weighted by total assets, which is justified given evidence in Appendix B that the predicted error term has a much higher standard deviation for smaller airlines. In such situations, weighted least squares (WLS) has efficiency gains above ordinary least squares (OLS).

the regressions are generally firms with fuel pass through agreements that are completely hedged even though they have relatively low levels of net worth.

Table 3 presents the regression coefficients that correspond to the scatter plots in Figure 4. Despite the small sample size, there is a robust and statistically significant positive correlation between net worth and hedging activity. In terms of magnitudes, the estimate in column 2 implies that a one standard deviation increase in the market net worth to assets ratio implies a one-half standard deviation increase in the fraction of expected jet fuel prices hedged. The coefficient estimate for the credit rating variable implies that a firm that moves one step down in our credit rating categorization reduces the fraction of expected jet fuel expenses hedged by 21% and assumes that this effect is linear across categories. In the last column, we include the credit rating categories separately as indicator variables. The largest decline (33%) in hedging occurs when a firm moves from BBB– or better to BB+, BB, or BB–; hedging declines by an additional 17% when a firm is downgraded to B+, B, or B–, although this estimate is only statistically distinct from the BB+, BB, BB– category at the 12% level of confidence; there is no additional decline in hedging when the firm is further downgraded to CCC+ or worse.

5.2 Hedging and net worth: Panel evidence

In Table 4, we isolate within-airline variation in measures of net worth using airline fixed effects regressions. As the columns show, the fixed effects estimates are positive and statistically different than zero at the 5% or lower significance level for every measure. Further, the magnitudes of the coefficients on credit ratings and market value of net worth are quite similar to the airline mean/between regressions in Table 3. The similarity of the sign and magnitude of the coefficients suggests that airline unobservable characteristics are not responsible for the strong positive correlation between net worth and the fraction of fuel expenses hedged. The coefficient estimates in the last column, for the specification in which we include each credit rating category separately, show a strong monotonic decline in hedging as a given firm moves down the credit rating spectrum. The coefficient estimates are statistically different from each other at the 5% level of confidence.

In Table 5, we present estimates from a first-differences specification. This should be viewed as a stringent test of the correlation given that the fraction of fuel expenses hedged is positively serially correlated among airlines, while the first differences are not positively serially correlated. This specification addresses the question whether changes in net worth from last year to this year for a given airline have a positive effect on the change in the fraction of next year’s expected jet fuel expenses hedged.

As the results in Table 5 show, the first-difference estimates are very similar to the

fixed effects estimates for all of the measures of net worth except for the book value. The estimates for the book value are slightly negative but the implied magnitude is quite small and not significant. The estimates for columns 2, 4, 5, and 6 imply that an increase in net worth for a given airline from last year to this year is correlated with an increase in the fraction of expected fuel expenses hedged.

The results in Tables 3 through 5 suggest that the positive relation between net worth and expected jet fuel expense hedging is robust. The coefficient estimates on most of our measures of net worth are similar when we isolate either across-airline or within-airline variation. This robust positive correlation provides strong support for the key predictions of our model. Since collateral constraints apply to both external financing and hedging activity, firms with low levels of net worth forgo risk management in favor of the preservation of internal resources.

6 Hedging around distress

Our theory predicts that severely constrained firms might not hedge at all. In this section, we document that airlines in distress cut their risk management dramatically. Moreover, we show that airlines facing tighter financial constraints state in their 10-K SEC filings that they are reducing their fuel price hedging because of collateral considerations, which is the basic mechanism in our model.

6.1 Evidence on hedging around airlines' distress

Received theory would predict that airlines in distress should engage in substantial risk management given the severe financial constraints they face. Along these lines, Morrell and Swan (2006) argue that "... when an airline is near bankruptcy, hedging fuel prices may make sense ... An airline near bankruptcy would like to protect itself from losses and thus the expense of becoming bankrupt ..." However, airlines in distress also consistently emphasize the importance of preserving cash and internal resources. Indeed, in contrast to received theory our model predicts that when the marginal value of internal resources is extremely high, firms reduce risk management. If risk management is subject to the same collateral constraints as external financing, then we should see a dramatic reduction in jet fuel price hedging as airlines become distressed.

We define a firm as being in distress, in our sample, when it is either rated CCC+ or below or is in bankruptcy. Panel A of Table 6 lists the 10 instances of distress in our sample. Both America West Holdings Corp. and U.S. Airways Group Inc. were downgraded to CCC+ or worse in 2001. U.S. Airways Group Inc. was subsequently

downgraded to CCC+ or worse again in 2004 before the merger with America West Holdings Corp. Seven other airlines entered distress during our time period. These instances were not simultaneous – two occur in 2001, three in 2004, two in 2008, and one each in 2002, 2003, and 2005.

Panel A of Figure 5 shows the average fraction of next year’s fuel expenses hedged in the two years before through the two years after entering distress for the 10 airlines which experience distress in our sample. From two years before to the year before distress, there is a slight drop in the fraction of fuel expenses hedged. But the drop in hedging in the year the firm enters distress is remarkable. Airlines go from hedging about 25% of their expected fuel expenses in the year before to less than 5% in the year entering distress. The fraction of fuel expenses hedged recovers in the two years after the initial onset of distress, although not to the levels seen two years prior.

Given this very large decline in hedging, it should come as no surprise that the drop is statistically significant at the 1% level. This is shown in Panel B of Table 6, where we regress the fraction of next year’s fuel expenses hedged on indicator variables for two years before through two years after entering distress. The estimates are robust to the use of WLS or airline fixed effects.

An alternative to studying firms’ hedging behavior in and around distress is to study firms’ hedging behavior in and around bankruptcy. We report such alternative results using an approach analogous to the above in Table A1 in the Appendix. Of the 10 instances of distress, only 7 result in bankruptcy. As firms approach bankruptcy, hedging drops substantially and in fact a significant drop occurs as early as 2 years before the airline enters bankruptcy. This suggests that it is entering distress, rather than bankruptcy per se, that is relevant for the drop in hedging.

The evidence in Table 6 is consistent with the idea that hedging becomes too costly for airlines in distress. Given the high marginal value of internal resources, companies facing collateral constraints on external financing are unwilling to use collateral to hedge future fuel price risk, as our model predicts. In the next subsection, we provide evidence from airlines 10-K filings that collateral concerns are the key driving force behind the drop in hedging by airlines in distress.

6.2 Evidence from 10-K SEC filings of airlines in distress

In this subsection, we provide evidence that directly supports the view that firms reduce hedging when facing distress in order to preserve collateral and internal funds. For the 5 years around distress for these 10 airlines, we read all mentions of fuel price hedging in the 10-K SEC filings of the airline. Panel B of Figure 5 shows the fraction of airlines

mentioning collateral or financing as a constraint on risk management for our airlines in and around distress. The fraction mentioning such concerns rises to 30% the year before distress and reaches 70% the year the airlines enter distress. It decreases to about 40% the year after distress and goes back down to zero subsequently. A majority of airlines in distress declare that collateral concerns are an impediment to hedging, consistent with our model.

To illustrate this point further, we provide some examples from our reading of these filings. Consider the case of ATA Holdings, whose financial condition deteriorates rapidly beginning in 2003, ending in bankruptcy in 2004. In their 2004 10-K filing, they disclose that

“[a]lthough many air carriers enter into ... derivative contracts to reduce the exposure to changes in fuel prices, the Company’s financial position has prevented ATA from hedging fuel prices in the past two years.”

In the two years prior to distress, ATA Holdings never mentions their financial condition when discussing their jet fuel hedging program.

America West Airlines provides a similar explanation for cutting their hedging program. From 1998 to 2000, the airline is rated B+ and hedges between 12% and 35% of their expected fuel expenses. In 2001, the airline is downgraded to CCC– and cuts their hedging to just 3% of expected fuel expenses. Their 2001 filing includes the following statement:

“In order to execute additional hedging transactions, we anticipate that we will have to provide cash collateral or other credit support, which we may not be able to provide in a cost-effective manner.”

The filings before distress never mention cash collateral as an impediment to its hedging program.

Another example is AMR Corporation, the parent company of American Airlines. From 1998 to 2000, AMR Corporation has a relatively strong balance sheet and financial position; their average book equity to assets ratio is 0.30 and their credit rating is BBB–. During this period, AMR Corporation hedges between 40% and 50% of their expected jet fuel expenses, and never mentions their financial condition or liquidity needs in their 10-K filing when discussing their jet fuel hedging program. AMR Corporation receives a significant negative shock to their balance sheet strength in 2001 due to the September 11th terrorist attacks. From 2002 to 2005, AMR Corporation carries either a BB– or B– rating and has a book equity to assets ratio that is close to 0. The extent of their hedging declines considerably to an average of only 11%. Further, in every year after 2001, AMR

Corporation notes in their 10-K filing that a further deterioration in their liquidity, credit rating, or financial position could negatively affect the Company's ability to hedge fuel in the future. This warning is new as of 2002.

The close link between financial condition and jet fuel price hedging is also supported by evidence from Morrell and Swan (2006). They note that "most newer carriers do not hedge at first because they are using their credit to finance high growth rates." They also report that "[i]n practice, cash-strapped airlines do sell profitable hedges early for cash. Delta Air Lines settled all their fuel hedge contracts before their maturity in February 2004, receiving proceeds of US\$83 million, almost all of which added to profits.¹⁶" Perhaps the strongest evidence comes from their analysis of fuel price hedging by airlines near bankruptcy:

"Unfortunately, it is at this very moment [when an airline is near bankruptcy] that acquiring oil price forward contracts is impossible or too expensive. Contracting future prices requires a guarantee that the company can pay the losses if the contract goes against the airline. No one wants a bet with someone who cannot pay off if they lose. An airline near bankruptcy cannot come up with the margin requirements (such as a bond or a line of credit) to back futures commitments. The authors have knowledge of several airline bankruptcies [Eastern, America West, TWA, National, Hawaiian, and United Airlines] and, in every case, financial officers recognized the advantage of a hedge, and understood that they were not in a position to make the appropriate trades in the marketplace.

There is a way to hedge that does not require a margin: airlines can buy a 'call' option that pays off above some upper bound on oil prices, but these options cost cash. In the one case where this was explored, the airline at risk could not make their business plan work if they had to pay for the oil price options."

While it is an empirical challenge to isolate the precise reason for the strong positive relation between net worth and hedging, the evidence in this section strongly supports the view that hedging plummets for firms in distress due to collateral considerations. In essence, the rationale firms provide for reducing risk management is exactly the mechanism of our model. This evidence supports our theory that the pledging of collateral is a key determinant of risk management.

¹⁶See the 2004 Annual Report of Delta Air Lines, p. F-22.

7 Robustness, alternative hypotheses, and policy implications

In this section, we show that the positive relation between measures of net worth and the extent of risk management is very robust and discuss alternative hypotheses and policy implications.

7.1 Robustness

The positive relation between measures of net worth and the extent of hedging is robust to restricting the sample to airlines that are not in distress, to considering subperiods in which oil prices rise or fall, to excluding Southwest Airlines, to excluding airlines with fuel pass through agreements, and to lease-adjusting assets.

The first concern we address is that our results are driven by firms in distress. This concern is partially mitigated in the specifications in Tables 3 and 4 that include the credit rating groups independently. In those results, the decline in hedging occurs for all three categories of poorly rated firms and the drop is in fact monotonic in the specification with airline fixed effects (see Table 4). As a further robustness test, Table 7 provides the estimates for all regression specifications excluding airline-year observations in which the airline is either in distress, that is, either rated CCC+ or worse, or in bankruptcy. The results are surprisingly similar; the relation between net worth and the extent of hedging is strong even among airlines outside of distress.

A second potential concern with the cross-sectional results is reverse causality. If hedging behavior is serially correlated, then hedging today may be positively correlated with net worth because net worth is positively affected by previous hedging behavior. This could be the case if jet fuel prices are rising, which as Figure 3 shows is true in much of the sample. In other words, airlines with high hedging might mechanically have high net worth because they made a good bet on oil price movements in the past. While our results exploiting within-airline variation in hedging with a first difference specification in Section 5 mitigate this concern, we address it here by showing that the cross-sectional positive correlation between net worth and hedging holds even in periods in which jet fuel prices fall. When jet fuel prices fall, airlines that previously hedged a large fraction of jet fuel expenses would lose money relative to airlines that hedged less. As Figure 3 shows, jet fuel prices fall in our sample from 1996 to 1998, from 2001 to 2002, and in 2009. We re-estimate the cross-sectional regressions for each oil price regime and present the estimates and 95% confidence intervals in Figure 6.

The coefficient estimates do not vary greatly across the different jet fuel price regimes

from 1996 to 2009. They are generally positive in all time periods, although statistical significance is lower in periods that include a small number of years (i.e., 2009). Second, the coefficients are positive even in the three periods over which oil prices fall. For example, on all six measures of current net worth, the correlation between hedging and the respective net worth measure is positive and statistically significant at the 5% level for the 2001 and 2002 period. Even when oil prices are falling and airlines that hedge are likely to experience smaller net gains (and potentially even losses) on their hedging positions, there is a strong positive correlation between hedging and measures of net worth as predicted by our theory.

A third concern is that Southwest Airlines, given its extensive hedging policy, might be an outlier that is influential for the results. We emphasize that the airline fixed effects and first difference specifications presented above considerably mitigate this concern. Since Southwest Airlines shows limited variation in measures of net worth over time, it is unlikely to drive the fixed effects or first difference estimates in Tables 3 and 4. Nevertheless, as a robustness check, we present coefficients from specifications that exclude Southwest Airlines in Table A2 in the Appendix, which are similar to our benchmark results. The statistical significance is reduced in a few of the specifications, especially in the cross section, which is perhaps not surprising as in asset weighted regressions removing Southwest Airlines amounts to removing about 10% of the sample. But overall, the results are robust.

A further concern is that airlines with fuel pass through agreements might affect our estimates, although the fixed effect and first difference specifications address this concern and these airlines are small which limits their effect on the estimates from our asset-weighted regressions. Indeed, estimates from specifications that exclude airlines with fuel pass through agreements at any point in the sample, reported in Table A3 in the Appendix, are rather similar to our benchmark results; in particular, the values of the estimates are very similar across all specifications. The cross section and fixed effect regressions yield statistically slight stronger results, while the first difference regressions yield statistically slightly weaker results.

Prior literature emphasizes the importance of leasing for financially constrained firms in general (see Eisfeldt and Rampini (2009), Rampini and Viswanathan (2011), and Rauh and Sufi (2011)) and for airlines in particular (see Benmelech and Bergman (2008) and Gavazza (2011)). We report specifications that adjust total assets for leased capital in the denominator of our measures of net worth in Table A4 in the Appendix. The lease adjustment amounts to capitalizing the value of operating leases as in Rampini and Viswanathan (2011) (Panel A) and Rauh and Sufi (2011) (Panel B). These specifications

are moreover weighted by total lease adjusted assets. The results are very similar and in fact often stronger.

7.2 Risk shifting and other alternative hypotheses

These robustness results provide further evidence on the strong positive correlation between measures of net worth and the extent of hedging. However, another concern is that the positive correlation might be the result of a mechanism different from the collateral constraints that we emphasize in our model. In particular, we address three alternative hypotheses that may explain this correlation: a bondholder shareholder conflict resulting in risk shifting, fixed costs and economies of scale, and the unwillingness of counterparties to enter into contracts with distressed firms.

The first alternative hypothesis is that shareholders of firms close to bankruptcy or liquidation have a convex payoff and therefore incentives to increase risk. Hence, such firms may prefer to “bet” on drops in fuel prices rather than hedge against fuel price increases. This hypothesis implies that firms close to bankruptcy or liquidation engage in speculation or at least abstain from hedging.

There are several reasons to be doubtful that risk shifting drives hedging decisions for airlines in our sample. First and foremost, as Section 6 demonstrates, 70% of airlines entering distress explicitly state that their ability to hedge is limited by collateral considerations and a weak financial position.

Further, many of the airlines in our sample explicitly state that they never use derivatives for speculation or trading purposes. As mentioned before, Southwest Airlines, for example, states that they “[do] not purchase or hold any derivative financial instruments for trading purposes.” Further, a text search of airlines’ 10-K filings for the string “hedg” within 3 lines of the string “speculat” or the word “trading” shows that among the 23 airlines in our sample, 15 airlines (65%) explicitly state they do not use derivatives for trading or speculative purposes. Among the 15 airlines without fuel pass through agreements, 12 airlines (80%) explicitly state they do not use derivatives for trading or speculative purposes. Of course, the other airlines may make similar statements that our search algorithm does not find. The vast majority of airlines in our sample declare outright that the purpose of their derivative positions is risk management, not trading or speculation.

Another reason to be skeptical of the risk shifting hypothesis is the evidence showing a strong correlation between net worth and the extent of hedging even when we exclude observations for years in which airlines are in distress (see Table 7). This is important because the main difference between the predictions of risk shifting and our theory is

that risk shifting predicts that we observe speculation and can imply a discontinuous hedging policy in which firms switch from hedging to speculation at a particular level of net worth (see, for example, Bolton, Chen, and Wang (2011)). We find no evidence of such speculative behavior by airlines in our data, and hedging and net worth are instead positively related even excluding distressed firms.

If risk shifting due to an ex post conflict of interest between shareholders and bondholders were a primary concern, one would expect that bondholders would require the firm to hedge a minimum amount. To the contrary, we find that bondholders of airlines in distress limit risk management, which is more consistent with our theory. For example, in their 2005 10-K, Delta Air Lines states:

“In December 2005, the Bankruptcy Court authorized us to enter into fuel hedging contracts for up to 30% of our monthly estimated fuel consumption, with hedging allowed in excess of that level if we obtained approval of the Creditors Committee or the Bankruptcy Court. In February 2006, we received approval of the Creditors Committee to hedge up to 50% of our estimated 2006 aggregate fuel consumption, ...”

Similarly, in their 2002 10-K, United Airlines writes:

“The terms of the DIP Financing limit United’s ability to post collateral in connection with fuel hedging.”

This suggests that creditors are mainly concerned that airlines pledge collateral to hedging counterparties thereby reducing the collateral backing their own claims.

Finally, while risk shifting remains a popular theory, the extant empirical literature finds little compelling evidence of risk shifting by firms in equilibrium. For example, Andrade and Kaplan (1998) “find no evidence that the distressed firms engage in risk shifting/asset substitution of any kind.” Indeed, Rauh (2009) finds that firms become more conservative in their asset allocation within defined benefit pension programs as they become distressed and concludes that his evidence “is consistent with the idea that risk-management dominates risk-shifting considerations, even as firms draw closer to bankruptcy.”

The findings of Andrade and Kaplan (1998) and Rauh (2009) are much more consistent with the statements made by airlines that hedging drops because of collateral and liquidity considerations, not because of risk shifting. To reinforce this point, we do a text search of airlines’ 10-K filings from our sample where we search for the term “liquidity” within three lines of the word “sufficient.” For firms rated BBB– or better, we find zero instances; for firms rated BB–, BB, or BB+, the incidence of these two terms appearing jointly

increases to 24%; for firms rated B+ or worse, this incidence increases to 55%. Airlines in our sample focus primarily on preserving collateral and liquidity when they enter distress; this, and not risk shifting, seems to explain why they cut back on hedging.

The second alternative hypothesis we address is that fixed costs or economies of scale explain the lack of hedging by small firms, as some authors have argued. However, our data is a panel and provides information on both the intensive and extensive margin of hedging rather than on the extensive margin only, that is, exploits the variation in the fraction of fuel expenses hedged, and we obtain a strong positive correlation within airlines over time, not just in the cross section. Such variation cannot be explained by fixed costs or economies of scale.

The third alternative proposes that counterparties are unwilling to enter into contracts with distressed firms for risk management purposes or at least that the collateral requirements substantially escalate when firms are downgraded to limit counterparty risk. Consistent with our theory, this alternative hypothesis requires that collateral considerations are a critical determinant of firms' hedging behavior. Indeed, if collateral requirements increase when firms are downgraded, this exacerbates the effects emphasized in our model. However, our theory shows that a change in the collateral requirements themselves is not required to understand the dynamics of risk management. Moreover, to the extent that in practice the hedging transactions are extensively collateralized at all times, the scope of this additional effect is limited. This second alternative would also not explain a reduction in hedging strategies that involve only purchased call options, as these do not involve promises from the firm to the hedging counterparty and hence should not be affected. It is also not consistent with our evidence showing that the strong correlation between net worth and the extent of hedging obtains even when we exclude observations for years in which the firm is in distress (see Table 7).

7.3 Policy implications

Recently, the collateral requirements of derivatives transactions have received considerable attention from policy makers. Our theory and empirical results speak to this debate. First, our results suggest that collateral is a first order determinant of risk management, even for large and relatively well capitalized firms such as Southwest Airlines, restricting corporate hedging. In our model, collateral is required to enforce repayment. However, if collateral requirements were raised above the level required for enforcement of repayment, this would raise the net worth needed for risk management and hence could substantially reduce corporate hedging by end users.

Second, risk management in our model can be implemented either by bundling the

financing and hedging transactions, akin to over-the-counter transactions, or by raising financing from lenders and engaging in hedging transactions with separate counterparties, akin to trading on a centralized exchange and arranging for credit lines separately. These are equivalent implementations in our model and hence the choice is neutral, suggesting that forcing transactions onto a centralized exchange per se does not raise collateral requirements.

Third, the neutrality-type result of our model provides a benchmark that may serve as a starting point for theories of why bundling financing and risk management may not be equivalent to trading on a centralized exchange with separate credit support. For example, separating financing and risk management transactions might result in additional enforcement problems or the provider of credit support may have limited information about whether funds are in fact used to meet collateral needs. We leave these questions for future research. Finally, our model does suggest that improvements in legal enforcement, say an increase in θ , would facilitate not just financing but also risk management.

8 Conclusion

Using hand-collected panel data on fuel price risk management by airlines we find remarkably strong support for the dynamic financing risk management trade-off proposed by Rampini and Viswanathan (2010, 2011) and extended to commodity price risk management in this paper. Airlines that are more financially constrained hedge less. Moreover, airlines whose financial condition deteriorates reduce risk management. Most dramatically, as airlines become distressed, airlines' fuel price risk management on average decreases from about 30% of estimated annual fuel expenses two years prior to distress to less than 5% in the year airlines become distressed. These empirical findings, both in the cross section and the time series, are consistent with the predictions of our dynamic model of risk management subject to collateral constraints, which explicitly considers input price risk management. In light of this strong empirical support for our dynamic theory of risk management, a reconsideration of the relation between financing and risk management is warranted.

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Table 1: Sample of airlines

This table lists the 23 airlines in the sample. First (last) year is the first (last) year that the airline is in the sample. Average assets represents the average total assets in 2005 USD millions of the airline across the sample period. Fuel pass through takes on the value 1 for airlines that at some point in the sample have a separate entity that bears the risk of fuel price movements.

	First year	Last year	Average assets	Fuel pass through
AMR CORP/DE	1996	2009	28370	0
DELTA AIR LINES INC	1996	2009	24815	0
UNITED CONTINENTAL HLDGS INC/UAL CORP	1996	2009	22111	0
NORTHWEST AIRLINES CORP	1996	2007	13860	0
CONTINENTAL AIRLS INC -CL B	1996	2009	10233	0
SOUTHWEST AIRLINES	1996	2009	10092	0
US AIRWAYS GROUP INC-OLD	1996	2004	9069	0
US AIRWAYS GROUP INC/AMERICA WEST HOLDINGS CORP	1996	2009	3666	0
JETBLUE AIRWAYS CORP	2000	2009	3350	0
ALASKA AIR GROUP INC	1996	2009	3251	0
REPUBLIC AIRWAYS HLDGS INC	2002	2009	2055	1
SKYWEST INC	1996	2009	1883	1
AIRTRAN HOLDINGS INC/VALUJET INC	1996	2009	1014	0
ATA HOLDINGS CORP/AMTRAN INC	1996	2004	828	0
MESA AIR GROUP INC	1996	2008	792	1
FRONTIER AIRLINES HOLDINGS	1996	2008	586	0
EXPRESSJET HOLDINGS INC	2000	2009	486	1
PINNACLE AIRLINES CORP	2001	2009	444	1
FLYI INC/ATLANTIC COAST AIRLINES INC	1996	2004	442	1
MIDWEST AIR GROUP INC	1996	2006	326	0
MIDWAY AIRLINES CORP	1996	2000	230	0
MAIR HOLDINGS INC/MESABA HOLDINGS INC	1996	2007	198	1
GREAT LAKES AVIATION LTD	1996	2009	113	1

Table 2: Summary statistics

This table presents summary statistics at the airline year level for the 23 airlines in the sample. The fraction of next year's fuel expenses hedged and whether a fuel pass through agreement is in place are collected directly from 10-K SEC filings. Other fuel variables are from Capital IQ. Net worth, credit rating, and operating income data are from S&P's Compustat. The core Compustat variables are constructed as follows: Net worth (bv) \$B: SEQ/1000; net worth to total assets (bv): SEQ/AT; net worth (mv) \$B: AT+PRCC_F×CSHO−CEQ−TXDB−LT; net worth to total assets (mv): net worth (mv) \$B divided by (ATCIQ+ME−CEQCIQ−TXDB); operating income to lagged assets ratio: OIBDP/AT(lagged); and credit rating: LRATING with CCC+ or worse = 1, B−, B, or B+ = 2, BB−, BB, or BB+ = 3, and BBB− or better = 4.

	N	Mean	SD	10th	50th	90th
Fraction of next year's fuel expenses hedged	244	0.385	0.389	0.000	0.240	1.000
Fraction for airlines without fuel pass through	183	0.200	0.238	0.000	0.120	0.500
Fuel pass through agreement in place	270	0.226	0.419	0.000	0.000	1.000
Fuel used, gallons	239	899	1038	29	367	2730
Fuel cost, per gallon	250	1.286	0.751	0.612	0.946	2.224
Fuel expense, total, \$M	263	1056	1601	23	326	3034
Fuel expense/total operating expense	263	0.198	0.090	0.109	0.171	0.334
Net worth (bv) \$B	270	0.458	2.837	-0.309	0.177	2.973
Net worth to total assets (bv)	265	0.189	0.291	-0.112	0.209	0.502
Net worth (mv) \$B	260	1.583	2.574	0.032	0.531	4.830
Net worth to total assets (mv)	260	0.324	0.245	0.041	0.260	0.706
Credit rating	157	2.401	0.861	1.000	2.000	4.000
Operating income to lagged assets ratio	260	0.118	0.136	-0.016	0.102	0.301

Table 3: Fuel expense hedging and net worth in the cross section

This table presents coefficient estimates of cross-sectional between (firm-mean) regressions relating the fraction of next year's fuel expenses hedged to measures of net worth in the current year. All regressions are weighted by total assets of the airline-year observation. For detailed definitions of the variables see the caption of Table 2.

	Dependent variable: Fraction of next year's fuel expenses hedged						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Net worth to total assets (bv)	0.750** (0.123)						
Net worth to total assets (mv)		0.725** (0.104)					
Net worth (bv), \$B			0.055* (0.020)				
Net worth (mv), \$B				0.031 (0.018)			
Operating income to lagged assets					4.096** (0.849)		
Credit rating						0.217** (0.017)	
Rating = BB-, BB, or BB+							-0.326** (0.069)
Rating = B-, B, or B+							-0.495** (0.073)
Rating = CCC+ or worse							-0.442* (0.158)
Constant	0.219** (0.039)	0.133** (0.045)	0.243** (0.037)	0.194* (0.073)	-0.062 (0.073)	-0.290** (0.047)	0.609** (0.035)
Observations	23	23	23	23	23	14	14
R-squared	0.358	0.318	0.199	0.127	0.544	0.748	0.798

** , * , + Coefficient statistically different than zero at the 1% , 5% , and 10% significance level , respectively

Table 4: Fuel expense hedging and net worth: Airline fixed effects

This table presents coefficient estimates of airline fixed effects regressions relating the fraction of next year's fuel expenses hedged to measures of net worth in the current year. All regressions are weighted by total assets of the airline-year observation. All regressions include year fixed effects, and standard errors are clustered at the airline level. For detailed definitions of the variables see the caption of Table 2.

	Dependent variable: Fraction of next year's fuel expenses hedged						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Net worth to total assets (bv)	0.385*						
	(0.138)						
Net worth to total assets (mv)		0.671*					
		(0.271)					
Net worth (bv), \$B			0.020**				
			(0.005)				
Net worth (mv), \$B				0.038**			
				(0.010)			
Operating income to lagged assets					1.313*		
					(0.499)		
Credit rating						0.176**	
						(0.028)	
Rating = BB-, BB, or BB+							-0.215*
							(0.074)
Rating = B-, B, or B+							-0.356**
							(0.071)
Rating = CCC+ or worse							-0.550**
							(0.110)
Observations	242	240	244	240	240	145	145
R-squared	0.656	0.663	0.664	0.690	0.653	0.645	0.647

**,*,+ Coefficient statistically different than zero at the 1%, 5%, and 10% significance level, respectively

Table 5: Fuel expense hedging and net worth: First differences

This table presents coefficient estimates of first difference regressions relating the fraction of next year's fuel expenses hedged to measures of net worth in the current year. Both the left hand and right hand side variables are first differenced. All regressions are weighted by total assets of the airline-year observation. All regressions include year fixed effects, and standard errors are clustered at the airline level. For detailed definitions of the variables see the caption of Table 2.

	Dependent variable: Δ Fraction of next year's fuel expenses hedged					
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Net worth to total assets (bv)	-0.112 (0.178)					
Δ Net worth to total assets (mv)		0.624+ (0.316)				
Δ Net worth (bv), \$B			-0.008 (0.015)			
Δ Net worth (mv), \$B				0.046+ (0.027)		
Δ Operating income to lagged assets					0.985+ (0.573)	
Δ Credit rating						0.136* (0.052)
Constant	0.113** (0.036)	0.070 (0.046)	0.113** (0.035)	0.049 (0.054)	0.099** (0.032)	0.058 (0.034)
Observations	210	208	212	208	208	125
R-squared	0.226	0.259	0.226	0.278	0.256	0.288

** , * , + Coefficient statistically different than zero at the 1%, 5%, and 10% significance level, respectively

Table 6: Fuel expense hedging around distress

This table presents evidence on fuel expense hedging and distress, where distress is defined to be when an airline is rated CCC+ or worse or, for unrated airlines, when the airline is in bankruptcy. Panel A lists the sample of airlines that are distressed. US Airways became distressed twice in the sample period (in 2001 and 2004). Panel B presents coefficient estimates of regressions relating the fraction of next year's fuel expenses hedged to indicators around the year in which airlines enter distress. Column 2 includes airline fixed effects. All regressions are weighted by total assets of the airline-year observation. All regressions include year fixed effects, and standard errors are clustered at the airline level.

Panel A: Sample of distressed airlines

	Year entering distress
US AIRWAYS GROUP INC/AMERICA WEST HOLDINGS CORP	2001
US AIRWAYS GROUP INC-OLD	2001
UNITED CONTINENTAL HLDGS INC/UAL CORP	2002
ATA HOLDINGS CORP/AMTRAN INC	2003
DELTA AIR LINES INC	2004
US AIRWAYS GROUP INC-OLD	2004
FLYI INC/ATLANTIC COAST AIRLINES INC	2004
NORTHWEST AIRLINES CORP	2005
FRONTIER AIRLINES HOLDINGS	2008
AIRTRAN HOLDINGS INC/VALUJET INC	2008

Panel B: Fuel expense hedging around distress

	Dependent variable: Fraction of next year's fuel expenses hedged	
	WLS	FE
	(1)	(2)
Two years before distress	-0.223 (0.132)	-0.134 (0.082)
One year before distress	-0.283+ (0.142)	-0.130 (0.093)
Year entering distress	-0.526** (0.100)	-0.380** (0.090)
One year after distress	-0.421** (0.120)	-0.222+ (0.108)
Two years after distress	-0.358** (0.099)	-0.172+ (0.094)
Observations	244	244
R-squared	0.229	0.689

** , * , + Coefficient statistically different than zero at the 1% , 5% , and 10% significance level , respectively

Table 7: Fuel expense hedging and net worth excluding distressed firm-year observations

This table presents coefficient estimates of regressions relating the fraction of next year's fuel expenses hedged to measures of net worth in the current year for cross section, firm-mean regressions, airline fixed effects regressions, and first difference regressions excluding distressed firm-year observations. Distressed airlines are defined to be those that are either rated CCC+ or worse or are in bankruptcy. All regressions are weighted by total assets of the airline-year observation. For detailed definitions of the variables see the caption of Table 2.

Dependent variable: Fraction of next year's fuel expenses hedged						
Measure of net worth	Net worth to total assets (bv)	Net worth to total assets (mv)	Net worth (bv), \$B	Net worth (mv), \$B	Operating income lagged assets ratio	Credit rating
	(1)	(2)	(3)	(4)	(5)	(6)
			<u>Cross section, firm-mean regressions</u>			
	0.985** (0.109)	0.708** (0.121)	0.068** (0.022)	0.030 (0.018)	3.773** (0.956)	0.254** (0.030)
			<u>Airline fixed effects</u>			
	0.399* (0.151)	0.500+ (0.249)	0.018* (0.007)	0.035** (0.006)	0.735* (0.350)	0.154** (0.032)
			<u>Airline first differences</u>			
	0.837+ (0.409)	0.509 (0.404)	0.094* (0.039)	0.040 (0.032)	0.829 (0.621)	0.185* (0.076)

**,*,+ Coefficient statistically different than zero at the 1%, 5%, and 10% significance level, respectively

Figure 1: Dynamic financing vs. risk management trade-off

Collateral constraints imply a trade-off between using current net worth w to finance investment and using it instead for risk management. When current net worth is sufficiently low, the firm is severely constrained and shifts as much net worth as possible to the current period and hence does not shift net worth from the high net worth state $w(\bar{s}')$ to the low net worth state $w(\underline{s}')$ next period. Financing needs override hedging concerns (see Proposition 3).

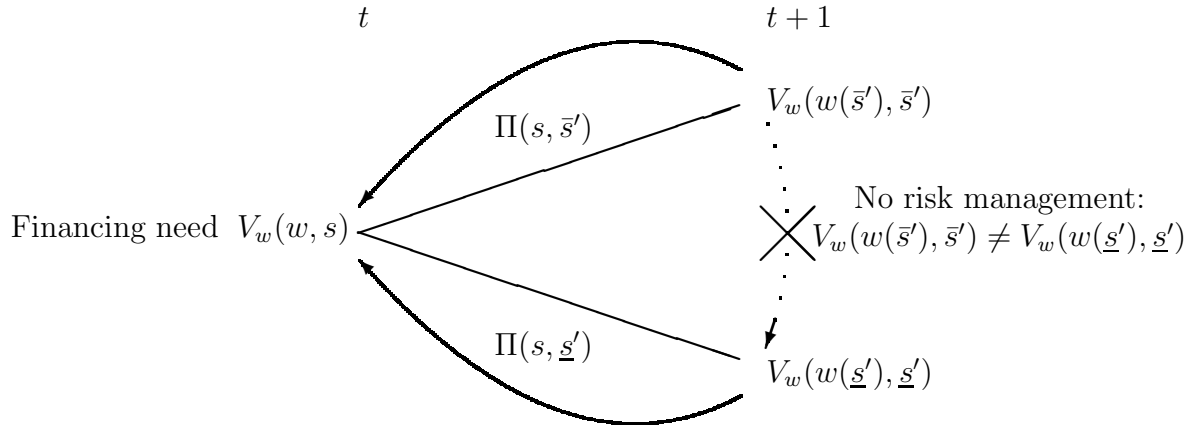
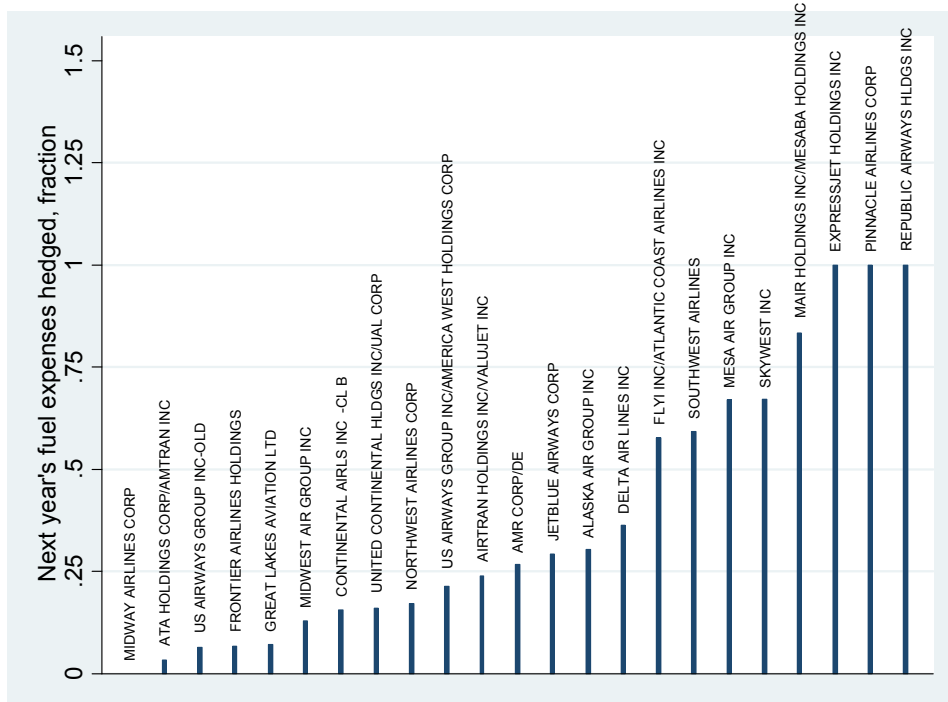


Figure 2: Fuel expense hedging by airline

This figure presents the average fraction of next year's fuel expenses hedged for each airline. The average is computed over all years the airline is in the sample. Panel A includes the full sample. Panel B excludes any airline that has a fuel pass through agreement at any point in the sample.

Panel A: Fuel expense hedging by airline: Full sample



Panel B: Fuel expense hedging by airline: Without fuel pass through airlines

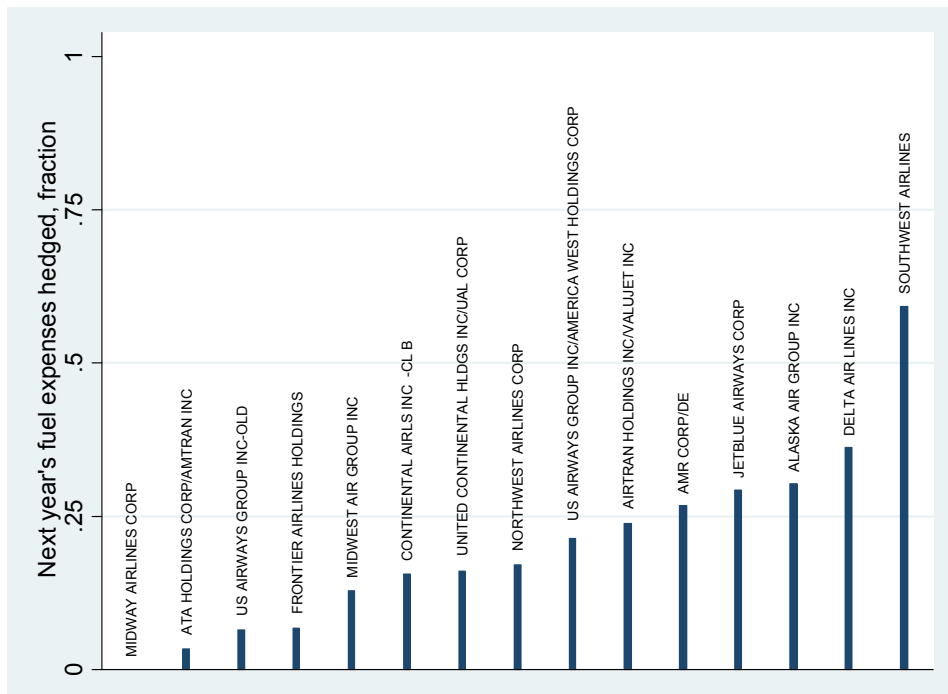


Figure 3: Fuel expense hedging in the time series

This figure presents the average fuel cost per gallon across airlines by year and the average fraction of next year's fuel expenses hedged across airlines by year. The longer dashed line represents the weighted average of next year's fuel expenses hedged where the weights are total assets of the airline.

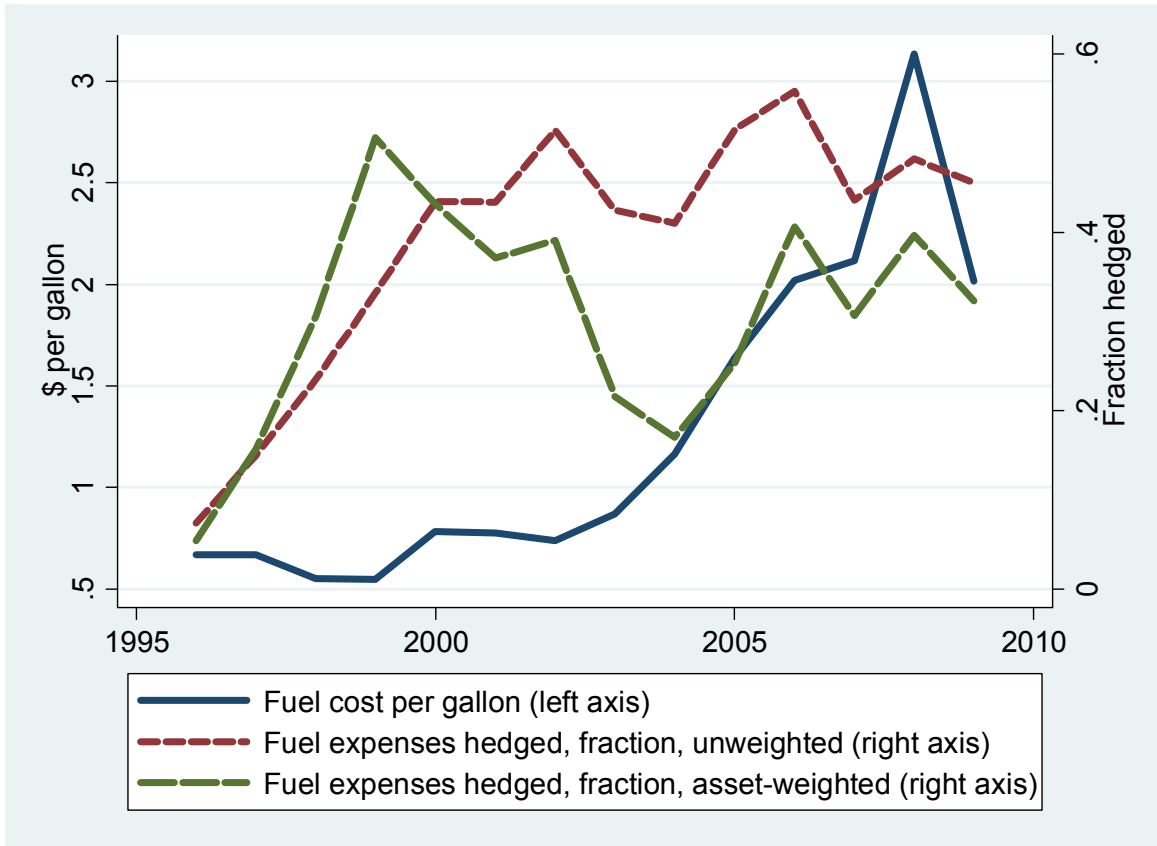


Figure 4: Fuel expense hedging and net worth: Cross-sectional evidence

This figure presents cross-sectional scatter plots of the fraction of next year's fuel expenses hedged and measures of net worth in the current year. All variables are averaged across years for each firm. The size of the circles reflects total assets, and the regression lines are based on (firm mean) asset weighted regressions.

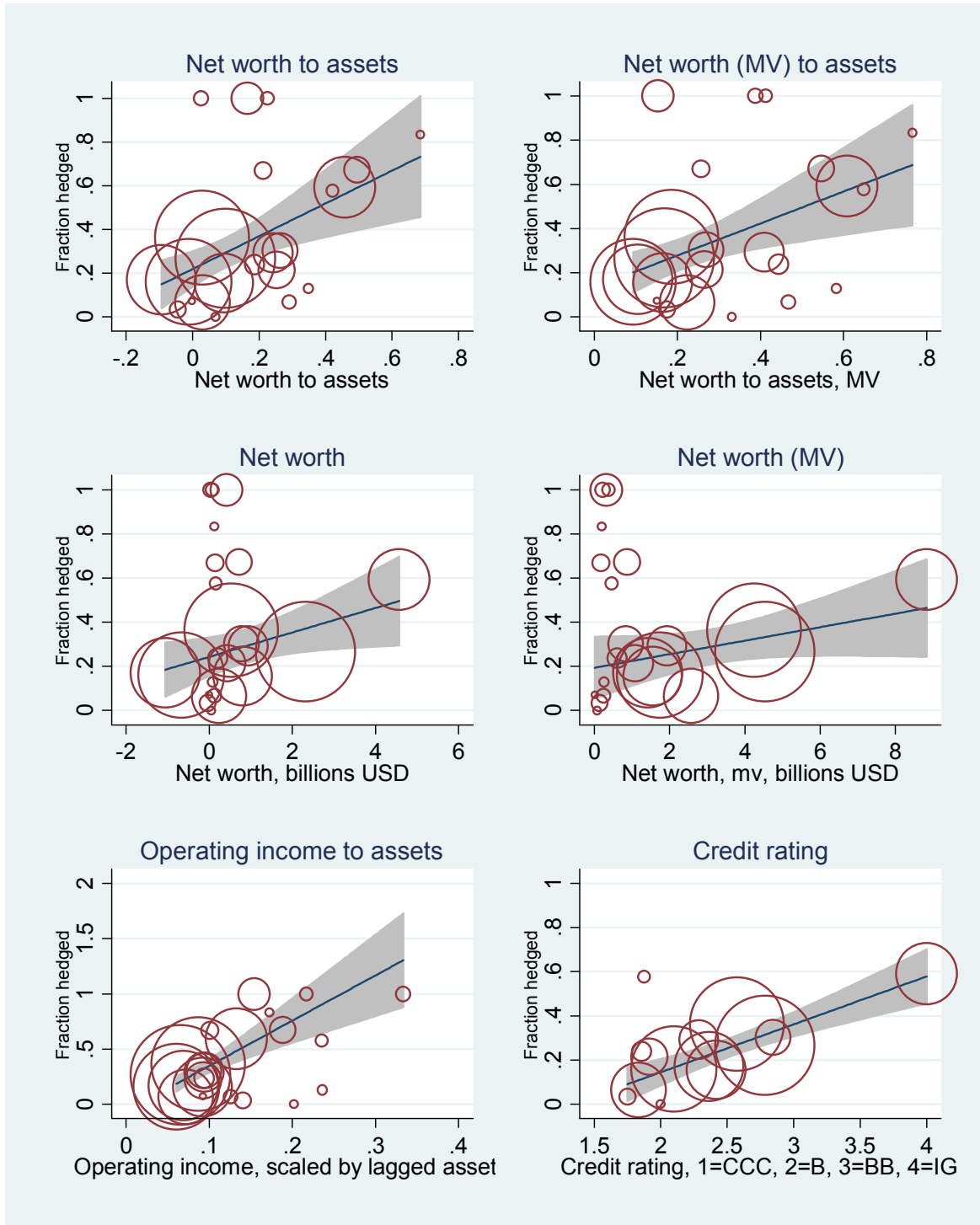
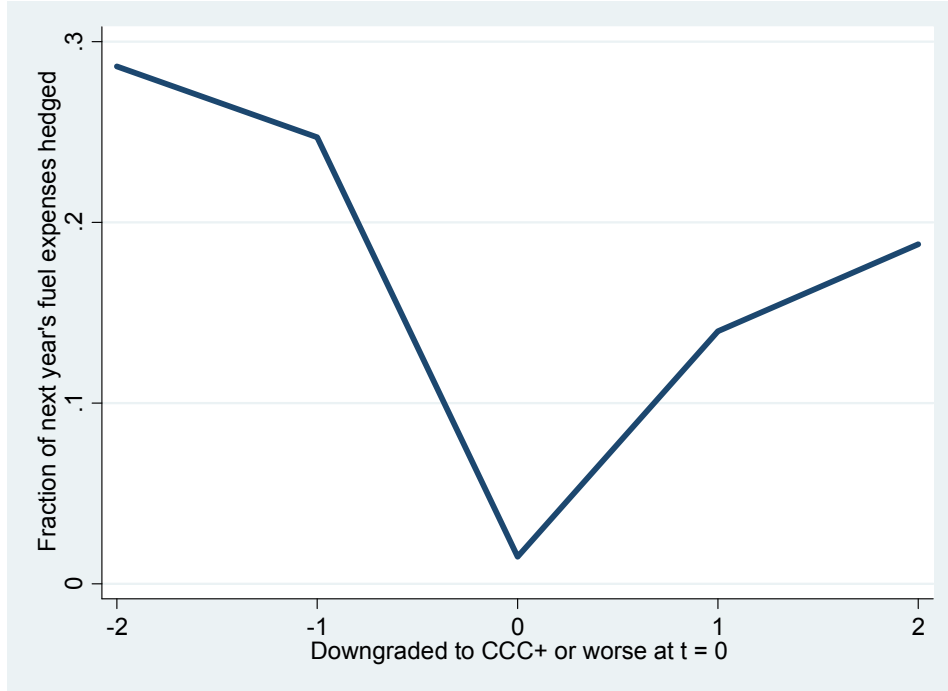


Figure 5: Fuel expense hedging around distress

This figure provides evidence on fuel expense hedging around distress, where an airline is defined to be in distress when the airline is rated CCC+ or worse or, for unrated airlines, when the airline is in bankruptcy. Panel A shows the fraction of next year's fuel expenses hedged for airlines that enter distress at $t = 0$. Each time period reflects a year. Panel B shows the fraction of airlines mentioning collateral or their financial position as a restriction on hedging activities.

Panel A: Fuel expense hedging around distress



Panel B: Fraction mentioning collateral/financial position as restriction around distress

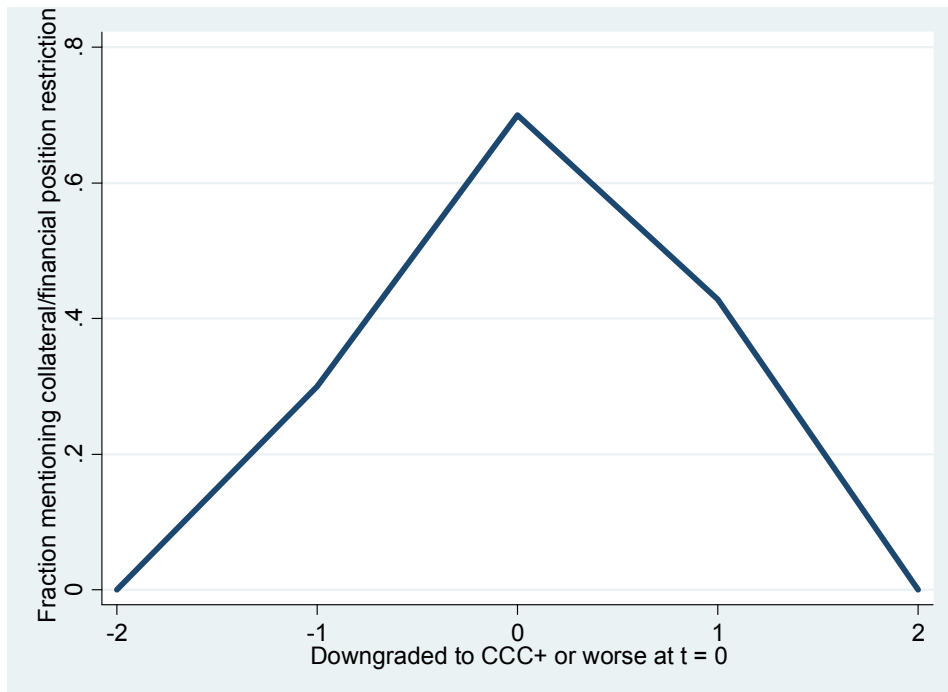
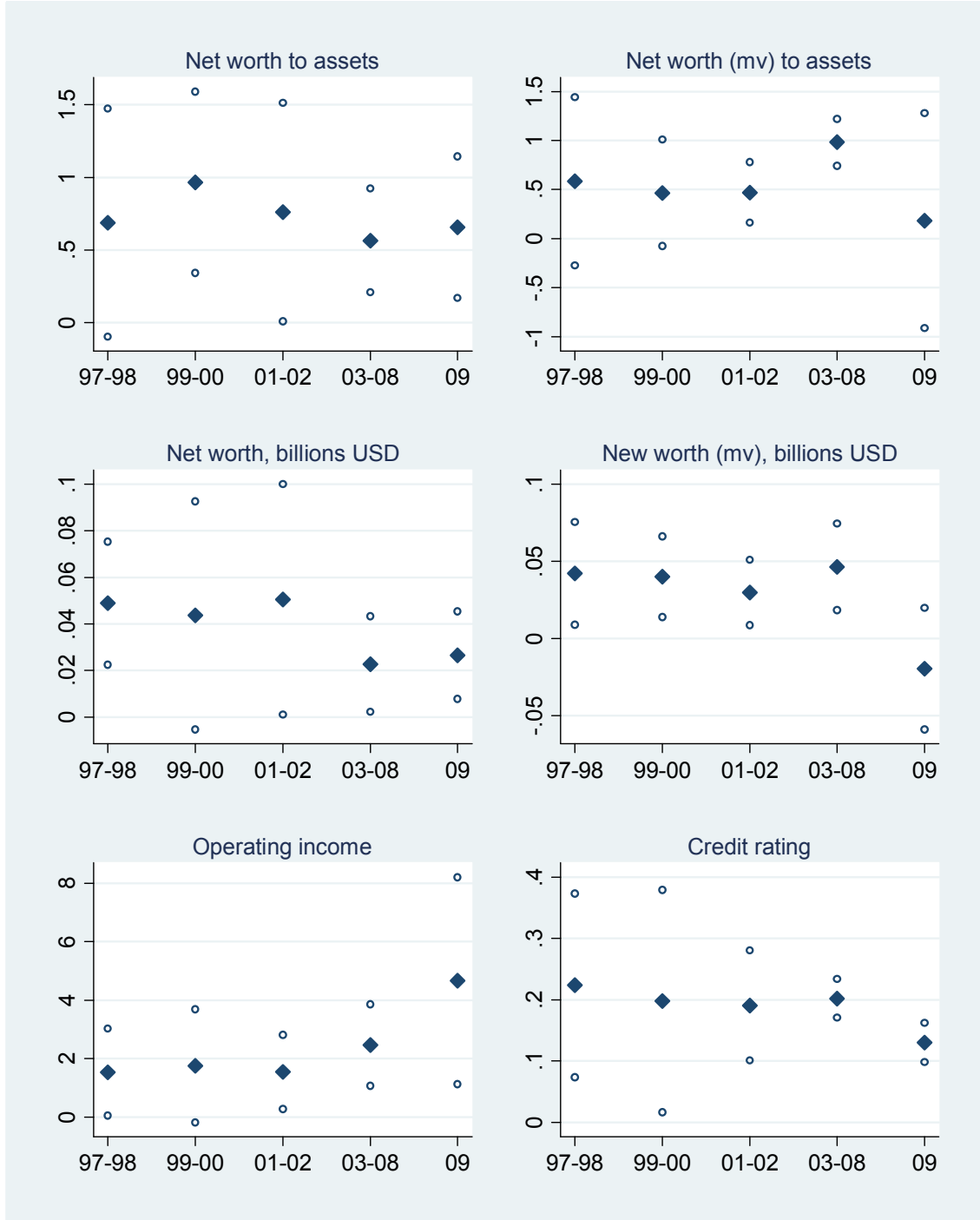


Figure 6: Fuel expense hedging and net worth across oil price regimes

For each measure of net worth, this figure presents coefficient estimates and 95% confidence intervals from cross-sectional regressions during different oil price regimes. From the periods 1997 to 1998, 2001 to 2002, and 2009, oil prices fell. For the periods 1999 to 2000 and 2003 to 2008, oil prices increased. All regressions are clustered at the airline level.



Appendix

Appendix A: Proofs

Proof of Proposition 1. The static profit maximization problem of the firm, given an amount of capital k is

$$\pi(k) \equiv \max_{x'} \widehat{A}' k^{\widehat{\alpha}} x'^{\phi} - p' x'.$$

The problem is concave in x' and hence the first order condition is necessary and sufficient. Solving the first order condition for the input demand function x' and substituting the solution into the objective we obtain the static profit function $\pi(k) = \widehat{A}'^{\frac{1}{1-\phi}} (1-\phi) \phi^{\frac{\phi}{1-\phi}} p'^{-\frac{\phi}{1-\phi}} k^{\frac{\widehat{\alpha}}{1-\phi}} = A' k^{\alpha}$ using the definitions provided in the statement of the proposition. Clearly, $\partial\pi(k)/\partial p' < 0$ and $\partial^2\pi(k)/\partial p'^2 > 0$, that is, the profit function is decreasing and convex in the price of the input good. \square

Appendix B: Weighted least squares (WLS) estimation

Weighted least squares estimation is a specific form of generalized least squares that can improve the efficiency of estimates under certain conditions. If there is heteroscedasticity and if there is a known variable that is a linear function of the degree of heteroscedasticity, weighted least squares with weights being the inverse square root of the known variable is a more efficient estimator than OLS.

Figure A1 below presents evidence that is suggestive of heteroscedasticity of the above form. To produce the figure, we first regress the fraction of next year's expected fuel expenses hedged on the market value of net worth to total assets (the graph is similar for other measures of net worth). The figure shows the standard deviation of the predicted residuals by the tercile of the book value of assets. As the figure shows, there is a strong negative relation between the standard deviation of the predicted residuals and the book value of assets. The pattern in the figure strongly suggests heteroscedasticity, and that the heteroscedasticity is a function of the size of the firm (as measured by the book value of assets). The WLS estimation down-weights smaller firms to take into account the additional noise from mismeasurement.

Figure A1: Heteroscedasticity by size

The figure shows the standard deviation of the predicted residuals (from a regression of the fraction of next year's expected fuel expenses hedged on the market value of net worth to total assets) by the tercile of the book value of assets.

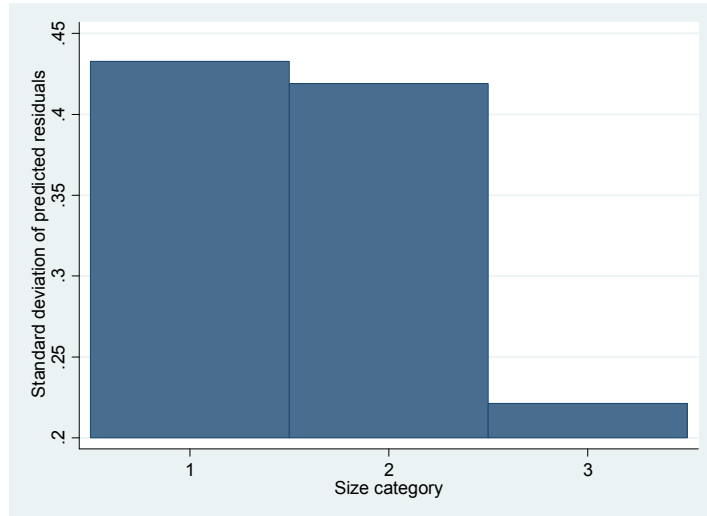


Table A1: Fuel expense hedging around bankruptcy (instead of distress)

This table presents evidence on fuel expense hedging around bankruptcy (instead of distress). Panel A lists the sample of airlines that file for bankruptcy. US Airways filed for bankruptcy twice in the sample period (in 2002 and 2004). Panel B presents coefficient estimates of regressions relating the fraction of next year's fuel expenses hedged to indicators around the year in which airlines file for bankruptcy. Column 2 includes airline fixed effects. All regressions are weighted by total assets of the airline-year observation. All regressions include year fixed effects, and standard errors are clustered at the airline level.

Panel A: Sample of airline bankruptcies

	Year entering bankruptcy
UNITED CONTINENTAL HLDGS INC/UAL CORP	2002
US AIRWAYS GROUP INC-OLD	2002
US AIRWAYS GROUP INC-OLD	2004
ATA HOLDINGS CORP/AMTRAN INC	2004
DELTA AIR LINES INC	2005
NORTHWEST AIRLINES CORP	2005
FRONTIER AIRLINES HOLDINGS	2008

Panel B: Fuel expense hedging around bankruptcy

	Dependent variable: Fraction of next year's fuel expenses hedged	
	WLS	FE
	(1)	(2)
Two years before bankruptcy	-0.351** (0.124)	-0.263** (0.068)
One year before bankruptcy	-0.450** (0.090)	-0.273* (0.102)
Year filing for bankruptcy	-0.563** (0.098)	-0.378** (0.107)
One year after bankruptcy	-0.319* (0.117)	-0.192 (0.143)
Two years after bankruptcy	-0.379** (0.108)	-0.231+ (0.118)
Observations	243	243
R-squared	0.210	0.681

**,*,+ Coefficient statistically different than zero at the 1%, 5%, and 10% significance level, respectively

Table A2: Fuel expense hedging and net worth excluding Southwest

This table presents coefficient estimates of regressions relating the fraction of next year's fuel expenses hedged to measures of net worth in the current year for cross section, firm-mean regressions, airline fixed effects regressions, and first difference regressions excluding Southwest Airlines. All regressions are weighted by total assets of the airline-year observation. For detailed definitions of the variables see the caption of Table 2.

Dependent variable: Fraction of next year's fuel expenses hedged						
Measure of net worth	Net worth to total assets (bv)	Net worth to total assets (mv)	Net worth (bv), \$B	Net worth (mv), \$B	Operating income lagged assets ratio	Credit rating
	(1)	(2)	(3)	(4)	(5)	(6)
	<u>Cross section, firm-mean regressions</u>					
	0.671** (0.213)	0.653* (0.232)	0.029 (0.022)	0.001 (0.026)	3.646** (0.922)	0.198** (0.061)
	<u>Airline fixed effects</u>					
	0.289* (0.113)	0.462 (0.274)	0.018** (0.004)	0.030* (0.012)	1.325* (0.512)	0.175** (0.034)
	<u>Airline first differences</u>					
	-0.141 (0.199)	0.450 (0.339)	-0.015 (0.013)	0.033 (0.027)	1.370** (0.450)	0.141* (0.056)

** , * , + Coefficient statistically different than zero at the 1%, 5%, and 10% significance level, respectively

Table A3: Fuel expense hedging and net worth excluding airlines with fuel pass through agreements

This table presents coefficient estimates of regressions relating the fraction of next year's fuel expenses hedged to measures of net worth in the current year for cross section, firm-mean regressions, airline fixed effects regressions, and first difference regressions excluding airlines with fuel pass through agreement at any point in the sample. All regressions are weighted by total assets of the airline-year observation. For detailed definitions of the variables see the caption of Table 2.

Dependent variable: Fraction of next year's fuel expenses hedged						
Measure of net worth	Net worth to total assets (bv)	Net worth to total assets (mv)	Net worth (bv), \$B	Net worth (mv), \$B	Operating income lagged assets ratio	Credit rating
	(1)	(2)	(3)	(4)	(5)	(6)
	<u>Cross section, firm-mean regressions</u>					
	0.646** (0.186)	0.678** (0.132)	0.062** (0.019)	0.053** (0.007)	3.588* (1.643)	0.221** (0.016)
	<u>Airline fixed effects</u>					
	0.409* (0.154)	0.849** (0.234)	0.020** (0.005)	0.037** (0.011)	1.577* (0.661)	0.175** (0.029)
	<u>Airline first differences</u>					
	-0.078 (0.211)	0.674+ (0.364)	-0.007 (0.010)	0.041 (0.025)	1.085 (0.804)	0.134* (0.053)

** , * , + Coefficient statistically different than zero at the 1%, 5%, and 10% significance level, respectively

Table A4: Fuel expense hedging and net worth with total lease adjusted assets

This table presents coefficient estimates of regressions relating the fraction of next year's fuel expenses hedged to measures of net worth in the current year for cross section, firm-mean regressions, airline fixed effects regressions, and first difference regressions using total lease adjusted assets. In Panel A, total lease adjusted assets are calculated as 8 times rental expense (see Rampini and Viswanathan (2011)) and in Panel B as in Rauh and Sufi (2011). All regressions are weighted by total lease adjusted assets of the airline-year observation. For detailed definitions of the variables see the caption of Table 2.

Dependent variable: Fraction of next year's fuel expenses hedged			
Measure of net worth	Net worth to total assets (bv) (1)	Net worth to total assets (mv) (2)	Operating income lagged assets ratio (3)
Panel A: Lease adjusted assets as in Rampini and Viswanathan (2011)			
	<u>Cross section, firm-mean regressions</u>		
	1.246** (0.181)	0.939** (0.149)	5.918** (1.833)
	<u>Airline fixed effects</u>		
	0.608** (0.199)	0.913* (0.331)	2.409** (0.660)
	<u>Airline first differences</u>		
	-0.205 (0.335)	0.952+ (0.464)	1.312 (0.854)
Panel B: Lease adjusted assets as in Rauh and Sufi (2011)			
	<u>Cross section, firm-mean regressions</u>		
	1.064** (0.173)	0.797** (0.134)	2.937* (1.351)
	<u>Airline fixed effects</u>		
	0.547* (0.196)	0.826* (0.347)	2.212** (0.715)
	<u>Airline first differences</u>		
	-0.057 (0.272)	0.782+ (0.413)	2.143** (0.734)

** , * , + Coefficient statistically different than zero at the 1%, 5%, and 10% significance level, respectively