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Dynamic risk management ☆

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ABSTRACT

Both financing and risk management involve promises to pay that need to be collateralized, resulting in a financing versus risk management trade-off. We study this trade-off in a dynamic model of commodity price risk management and show that risk management is limited and that more financially constrained firms hedge less or not at all. We show 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.

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, such as small firms, are more likely to manage risk. The main robust pattern that emerges from this literature is that small firms engage in less risk management, leading Stulz (1996) to conclude that "[t]he actual corporate use of derivatives, however, does not seem to correspond closely to the theory" (page 8).

In this study, we challenge the notion that financial constraints and risk management should be positively correlated theoretically and empirically. We provide a model that predicts that commodity price risk management should be lower and even absent for firms that are more financially constrained. The basic theoretical insight 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, a trade-off emerges between financing and risk management. Commodity price risk management shifts net worth across states, and firms are effectively risk averse about net worth. 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, or downsize less, at the expense of hedging. Consistent with our model,

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American Airlines, for example, notes in its 2009 10-K Securities and Exchange Commission (SEC) filing that "[a] deterioration of the Company's financial position could negatively affect the Company's ability to hedge fuel in the future."

We explicitly consider input price hedging—for example, fuel price hedging by airlines—in a dynamic neoclassical model wherein firms require capital and an input to produce output next period. Input spot prices are stochastic, and the firm can purchase inputs in the spot market or contract to purchase the input in a state-contingent way in advance. Such a promise to purchase a specific quantity of inputs in some state next period at a prespecified price that exceeds the spot price needs to be collateralized. These promises as well as the promises to repay loans count against collateral constraints, resulting in a trade-off between financing and risk management. High input prices result in low cash flows and, hence, low net worth. Collateral constraints render the firm effectively risk averse in net worth, providing a rationale for input price risk management. Importantly, firm value is concave in net worth and, because input price hedging shifts net worth across states, the firm could hedge input prices, even though the profit function is convex in spot prices, as is standard in neoclassical production theory and unlike in the ad hoc approach often used in the literature. Collateral constraints imply a basic trade-off between financing and commodity price risk management similar to the one identified by Rampini and Viswanathan (2010, 2013) in the context of productivity risk. This trade-off implies that 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, or be forced to downsize less, leaving no room for risk management.

We examine the empirical predictions of the model by analyzing jet fuel price hedging by US airlines. This empirical setting is ideal for a number of reasons. First, jet fuel expenses represent a very large component of total operating expenses for airlines. On average, they are about 20% in our sample. 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, a number of financial instruments 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 at both the extensive and intensive margin in contrast to most of the previous literature. 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. For example, Southwest Airlines in its 2010 10-K SEC filing explicitly states that its jet fuel price hedges are collateralized with owned aircraft, which is exactly the mechanism linking collateral, financing, and hedging in our model. This tight link between collateral requirements and risk management decisions is largely 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 US 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 Standard and Poor's (S&P) 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, whereas most previous studies cannot separately exploit within-firm variation in part because many of them use cross-sectional data or data with a limited time series dimension only and in part because they largely rely on dummy variables for derivatives use that have only limited within-firm variation.

We first show that almost no airline hedges 100% of its jet fuel price risk for the next year and that hedging is completely absent for a large number of airlines. Thirty percent of the airline-year observations involve no hedging, and the average hedging is only 20% of expected jet fuel expenses among airlines without fuel pass through agreements.[1]

Using several measures of net worth, the empirical counterpart of the key state variable in our model, 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, that is, cross-sectional variation only, 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 1 standard deviation increase in the market value of net worth scaled by the market value of the firm is associated with a 0.5 standard deviation increase in the fraction of next year's fuel expenses hedged. Because this correlation obtains even when net worth is scaled by assets, it is not simply a reflection of the well-known size pattern in risk management.

The strong positive correlation between measures of net worth and hedging also holds within airlines over time, a dimension that few studies are able to exploit separately. 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. Moreover, we instrument for net worth using operating income, as variation in operating income due to variation in productivity is the main source of idiosyncratic net worth variation in the model. The two stage least squares estimates are qualitatively similar.

[1] A fuel pass through agreement is part of an overall agreement in which a regional airline provides jet service on a code sharing basis on behalf of a major carrier, which is responsible for the scheduling, pricing, and marketing of the route and provides the jet fuel.

Perhaps the most compelling evidence comes from examining the dynamics of risk management around financial distress. Our data cover ten 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%. Thus, risk management drops dramatically as airlines approach distress and recovers only slowly thereafter. We are the first, to the best of our knowledge, to show this remarkable pattern. This pattern seems puzzling from the vantage point of extant theories, but it corroborates the prediction of our theory that severely constrained firms reduce risk management and might abandon it completely.

To further understand the reasons that 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 collateral constraints are the more plausible explanation for our findings.

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 management 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" (p. 1629). They and the empirical literature following their work interpret 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" (p. 1108).

However, the empirical literature finds precisely the opposite size pattern in the data. For example, Nance, Smith, and Smithson (1993) find that firms which do not hedge are smaller and pay lower dividends, in cross-sectional survey data on derivatives use for large industrial firms. Similarly, Géczy, Minton, and Schrand (1997) find a strong positive relation between derivatives use and firm size in a cross section of large US firms.[2] In light of this tension between the theory and practice of risk management by corporations, 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" (p. 8). Even Froot, Scharfstein, and Stein (1993) note this tension: "Nance, Smith, and Smithson (1993) … 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" (p. 1653).

In the context of jet fuel price hedging by airlines, Carter, Rogers, and Simkins (2006a, 2006b) study the effect of hedging on firm value. They also provide some evidence on the determinants of jet fuel hedging. Carter, Rogers, and Simkins (2006b) find that "the more active hedgers of fuel costs among airlines are the larger firms with the least debt and highest credit ratings" (p. 33) and conclude that "[t]his result is somewhat surprising, at least to the extent the smaller airlines might be expected to have larger financial distress costs … and hence greater motive to hedge" (p. 33). They argue that this could be due to fixed costs, lack of sophistication, or, contradicting the hypothesis, lower distress costs of smaller airlines.[3] Thus, they do not recognize the financing risk management trade-off, do not use the net worth variable suggested by

[2] They 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%.

[3] Specifically, they write in their conclusion that "[o]ne explanation is that the smaller airlines have lacked either sufficient resources or the strategic foresight to acquire a derivatives hedging capability. A second possibility—one that is consistent with our main findings—is that the largest airlines also have the highest costs of financial distress" (p. 33). Morrell 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.

our theory, and do not exploit within-airline variation separately. Instead, their study focuses on the effect of hedging on firm value. In contrast, we use the time series dimension of our panel data to study the relation between net worth, the state variable our theory suggests, and risk management within airlines over time and to show the remarkable dynamics of risk management around financial distress.

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. The airlines in our sample hedge the cost of a major input, jet fuel, although our model shows that no conceptual difference exists between hedging input and output prices. Tufano has data for only three years that are effectively cross-sectional, whereas we have panel data for (up to) 15 years. He 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, such as dividend yields, is somewhat mixed in such cross-sectional studies, the one relatively robust pattern that emerges, the positive relation between hedging and firm size, is consistent with our theory and empirical results. 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 could 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.

The positive relation between hedging and size is typically interpreted as evidence of economies of scale in the literature [see, for example, Mian, 1996, in addition to the papers mentioned above]. Previous work does at times tangentially note also the positive relation between hedging and dividend yields, to the extent that such a positive relation is found. However, the relation between hedging and net worth predicted by our model has not been carefully established and it has not been explored in detail before. This might seem surprising as the correlation we find is so remarkably strong and positive. One reason is that previous studies typically use neither panel data nor data on the intensive margin of hedging. 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. Finally, the choice of the explanatory variable, net worth, in our empirical work is guided by theory, while the variables used in previous work are motivated on intuitive grounds only. In any case, we are the first to show and carefully investigate the strong positive correlation between and joint dynamics of hedging and net worth.

The theoretical literature includes several studies of the link between financial constraints and corporate risk management. 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, no trade-off between financing and risk management is found in their model. Holmström and Tirole (2000) note that credit-constrained entrepreneurs could 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 could 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, 2013) study this trade-off in a similar environment but do not consider commodity price risk management, which is arguably the most common form of risk management in practice. They also discuss the related literature on dynamic firm financing.[4]

Finally, 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 (see also Fehle and Tsyplakov, 2005). This type of agency problem, however, implies that distressed firms should engage in speculative trading. We discuss this alternative hypothesis is Section 7.2. 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, and they choose their investment, financing, and risk management policies given

[4] The 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 that allows higher leverage (see, for example, Mayers and Smith, 1982; Smith and Stulz, 1985), managerial risk aversion (see, for example, Stulz, 1984), and information asymmetries between managers and shareholders (see DeMarzo and Duffie, 1995; Breeden and Viswanathan, 1998). Adam, Dasgupta, and Titman (2007) and Mackay and Moeller (2007) study risk management using an ad hoc approach in which hedging is modeled as reducing the variance of the input price or another parameter itself. As we discuss in Section 3, this approach is problematic in our view as in standard production theory profit functions are convex in input prices and appropriately chosen parameters, undermining the rationale for risk management.

collateral constraints. Firms are effectively risk averse in net worth and thus could hedge, despite the fact that in our model, consistent with standard neoclassical production theory, profit functions are convex in input prices. 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 $\widehat{A}'k^{\widehat{\alpha}}x'^{\phi}$ with $\widehat{\alpha} > 0$, $\phi > 0$, and decreasing returns to scale, i.e., $\widehat{\alpha}+\phi < 1$.[5] 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 one. The price of the output good is subsumed in the total factor productivity $\widehat{A}' > 0$, which is stochastic. We denote the exogenous state by $s \equiv (\hat{A}, p)$ and assume that the state $s \in S$ follows a joint Markov process in which 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 $R < \beta^{-1}$, ensuring that firm financing matters even in the long run. These lenders have deep pockets in all dates and states, and they 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 that delivers one unit of the input at price p_f' in state s' 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 it is the net promises $(p'-p_f')x_f'$ that count against the collateral constraint.

3.2. Commodity price risk management

Taking the amount of capital k as given, the firm's input choice is a static profit maximization problem. Hence, 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': $A' \equiv \widehat{A}'^{1/(1-\phi)}(1-\phi)\phi^{\phi/(1-\phi)}p'^{-\phi/(1-\phi)}$ and $\alpha = \widehat{\alpha}/(1-\phi)$.

The proof is in Appendix A. The profit function is convex in the spot price of the input p', as is well known in neoclassical production theory. However, hedging by agreeing to purchase an amount x_f' at price p_f' leaves the spot price itself unchanged and does not affect the firm's input choice, as the firm evaluates inputs at the spot price even if it hedges, because it can still buy or sell additional inputs at that price. 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. Because the firm is as if risk averse about net worth, as we show below, the firm could want to hedge states in which the input price is high to ensure sufficient net worth to operate going forward.

We now argue that hedging commodity price risk is equivalent to hedging net worth. 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.[6] 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

[5] The assumption of decreasing returns to scale yields a model with plausible implications for firm dynamics in terms of financing, investment, and risk management. With constant returns but no adjustment costs, firms would hedge the highest productivity state (see Rampini and Viswanathan, 2010), but such a model would not have plausible implications for firm dynamics. With constant returns to scale and convex adjustment costs, as in the standard neoclassical model, the state variable would be net worth to capital, and we conjecture that the implications of such a model in terms of the relation between risk management and that state variable would be similar to ours. However, the relation between size and financing, investment, and risk management observed in the data provides a challenge for the model with constant returns to scale.

[6] Critically, the quantity underlying the forward contract could differ from the amount of input goods 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.

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 credible only if it is collateralized. We summarize this insight in Proposition 2:

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

$$\theta k(1-\delta) \geq Rb' + (p_f' - p')x_f',$$

for each state s' next period. 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 (for state s'), 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 $R^{-1}\theta(1-\delta)$ per unit of capital and hedging h' subject to short-sale constraints $h' \geq 0$, for each state s' next period.

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. 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 $\wp \equiv 1 - R^{-1}\theta(1-\delta)$ (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 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:

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

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

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

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

and the short-sale constraints, for each state s' next period,

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

The budget constraint for the current period (2) states that current net worth can be spent on dividends 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 $\mathrm{E}[R^{-1}h'|s]$. The budget constraints for next period (3) state that, for each state s', profits from production using the optimal amount of the input good $A'f(k)$, the resale value of capital net of debt $(1-\theta)k(1-\delta)$, and the payoffs of the contingent claims h' determine the firm's net worth w' going forward. The program, moreover, requires that dividends d, capital k, and net worth w' are non-negative. Let $z \equiv (d, k, w', h')$ and define the set $\Gamma(w,s)$ as the set of $z \in \mathbb{R}_+^{2+S} \times \mathbb{R}^S$ such that (2) through (4) are satisfied. The set $\Gamma(w,s)$ is convex. Thus, the problem is well defined and, using standard arguments, a unique value function exists that solves the fixed point problem. This value function is strictly increasing in net worth w and concave in w. The value function is strictly concave in net worth below a state-contingent dividend threshold $\overline{w}(s)$, $\forall s \in S$. Our model of commodity price risk management thus maps into the environment with only productivity shocks studied by Rampini and Viswanathan (2013), and we defer to that paper for proofs that are not provided here.

The concavity of the value function that solves the firm's problem in (1) through (4) is the motivation for risk management. 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.

We stress that this insight calls into question the ad hoc approach often used in the risk management literature when risk management is modeled simply as reducing the variance of an input price or another parameter. In our view, this approach is problematic for two reasons. First, it assumes that a hedged firm can buy or sell any quantity at the hedged price and, thus, evaluates input purchases and production decisions at that price, whereas in practice the quantity underlying a hedge is typically fixed and marginal decisions are based on the spot price. Second, standard production theory implies that profit functions are convex in input prices, which means that there is no rational to hedge using this approach and there would be a motive for speculation instead.[7]

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.

[7] This approach is used, for example, in Adam, Dasgupta, and Titman (2007) and Mackay and Moeller (2007). In light of this, the latter are forced to assume that the profit function is concave in prices instead of convex.

The simplest case of this is when 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, as such claims do not expand the space of credible promises. 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.[8]

3.3. The financing risk management trade-off

Our theory has two important implications. First, firms engage only in limited risk management. Second, firms that are more financially constrained engage in less risk management; that is, an important link exists between firm financing and risk management. These implications are consistent with the basic size pattern 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 spelled out in Proposition 3:

Proposition 3 (*No risk management by severely constrained firms*). *Firms that are severely financially constrained, that is, firms with sufficiently low net worth, do not engage in commodity price risk management.*

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

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

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 because 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, because the budget constraint implies that $w \geq \wp k$. 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

$$1 \geq \Pi(s,s')\beta \frac{V_w'}{V_w} \frac{A'\alpha k^{\alpha-1} + (1-\theta)(1-\delta)}{\wp}, \tag{6}$$

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

$$R^{-1} \geq \beta \frac{V_w'}{V_w}, \tag{7}$$

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. The result obtains for any Markov process $\Pi(s,s')$ and does not require any additional assumptions.

The intuition for this result, which is illustrated in Fig. 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 to be able to deploy as much capital as possible. As a result, the firm does not engage in risk management. Issuing promises to pay against high net worth states next period 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. Thus, collateral constraints link financing and risk management. We emphasize that severely constrained firms with low net worth due to low cash flow realizations could be forced to downsize because of their low net worth but choose to use their entire (limited) net worth to finance capital going forward, that is, downsize as little as possible, instead of using some of it to engage in risk management.[9]

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 straight forward. 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, effectively ensuring 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,*

[8] The model can be easily adapted to handle other types of risk, such as currency and interest rate risk. 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 $\hat{A}'$. Similarly, we 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 $\wp(s) \equiv 1 - R(s)^{-1}\theta(1-\delta)$ depend on the state $s \in S$.

[9] Because our model features complete markets on the subspace of collateralized trades, forwards and futures can be replicated. Thus, 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.

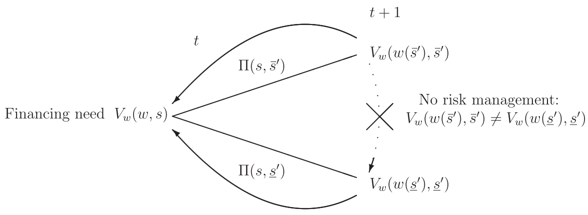

Fig. 1. Dynamic financing versus risk management trade-off. Collateral constraints imply a trade-off between using current net worth w to finance investment and using it instead for risk management. When current net worth is sufficiently low, the firm is severely constrained and shifts as much net worth 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).

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

$$A(s')k^{\alpha}+(1-\theta)k(1-\delta)+h_p(s')=A(\hat{s}')k^{\alpha}+(1-\theta)k(1-\delta)+h_p(\hat{s}'), \tag{8}$$

that is, the sum of the payoff of the hedging policy plus the profit from operations and the resale value of capital net of debt is constant across states that are hedged. Because 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, as asserted. Such a payoff could be implemented in practice by purchasing a portfolio of call spreads.

Above we conclude that severely constrained firms could abstain from risk management. Moreover, Rampini and Viswanathan (2013) show that firms abstain from risk management with positive probability under the stationary distribution of firm net worth. This result is particularly relevant here, as in the data many mature firms abstain from risk management and firms discontinue risk management if their financial condition deteriorates sufficiently. In fact, this result predicts exactly that: A sufficiently long sequence of high commodity prices and, hence, low profits eventually result in even mature firms getting so financially constrained that they stop hedging.

Proposition 3 and the result about the absence of risk management under the stationary distribution provide the key empirical predictions of our model.[10] In the cross section, more constrained firms engage in less risk management and might not engage in risk management at all, and, in the time series, as firms' financial conditions deteriorate (improve), they reduce (increase) the extent of risk management and could stop hedging completely (could initiate risk management). We test these predictions using the airline industry as our empirical laboratory in the remainder of the paper.

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, jet fuel is a major expense for airlines, accounting for 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 from those for other firms. The data set is based on hand-collected information from US airlines' Form 10-K, Item 7(A), which provides Quantitative and Qualitative Disclosures about Market Risk. In particular, the time series dimension of our panel data on the extent of risk management, as opposed to only data on whether or not firms hedge, allows us to study the within-firm relation between net worth and hedging. 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 US airlines

The sample we use in our analysis covers 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 a Standard Industrial Classification (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. Fifty-two airlines qualify by this broad definition. Of the 52 companies, 13 are not commercial passenger airlines—such as FedEx Corp., Airborne Inc., and Air Transport Services Group—and we exclude these.

From the remaining 39 airlines, we drop seven 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 nine airlines for which we have fuel hedge data for less

[10] The numerical results in Rampini and Viswanathan (2013) show monotonic behavior of the hedging policy independent of the persistence of productivity, although there is no general monotonicity result.

than five years. This 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 nine airlines are in the sample for only one year, and eight of the nine are in the sample for less than four 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 presented 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. Much of the regional jet service of major US airlines is provided by regional airlines that operate flights on behalf of major carriers in a code sharing agreement with a fixed-fee arrangement, in which the major carriers pay the regional carriers a fixed rate per flight and are responsible for scheduling, pricing, and marketing of these routes and provide the jet fuel and, hence, bear the fuel price risk under a fuel pass through agreement. We code airlines with fuel pass through agreements as hedging 100% of next year's expected fuel expenses. However, we argue that such agreements are not independent decisions to hedge fuel price risk, but rather just one aspect of an overall code sharing agreement (see Appendix B for a more detailed discussion). In fact, such regional airlines are essentially wet lease companies. A wet lease is a leasing agreement in which the lessor provides the aircraft including crew, maintenance, etc., to the lessee. Thus, one could argue that airlines with fuel pass through agreements are in the leasing industry and should be excluded from the analysis, as we do in our robustness results. 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 its 2008 10-K filing, United Airlines directly links its 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. … 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 its 2009 10-K filing, JetBlue Airways stresses the role of liquidity concerns and collateral requirements in the unwinding of their fuel hedging program: “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 how the sharp drop in jet fuel prices in the second half of 2008 led to $70 million in payments to hedging counterparties affecting Airtran's 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, its 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 its 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.” Its 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.[11] The gross

[11] In its 2010 10-K the airline elaborates: “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

positions in fuel derivatives were sizable. 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 significant 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 because 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. The 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.[12] Southwest explains the purpose of its hedging in its 2010 10-K as follows: "[J]et fuel and oil typically represents one of the largest operating expenses for airlines. … The Company utilizes financial derivative instruments … as a form of insurance against the potential for significant increases in fuel prices." It explicitly states 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 … qualify for hedge accounting." Southwest's discussion of its 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. Airlines with fuel pass through agreements tend to be regional carriers that are less familiar as they mostly operate under their code-sharing partners' name. We discuss the nature of these agreements in Section 4.1 and in Appendix B.

Table 2 presents summary statistics. Across airline-year observations, the average fraction of next year's expected fuel expenses hedged is 38%. However, this average is skewed by the 22% of observations for which a fuel pass through agreement is in place. 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 next year's 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% or more 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 Table 2.

Panel A of Fig. 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 Panel B, we remove airlines that have fuel pass through agreements at some point in the sample. When we eliminate these seven airlines, Southwest Airlines is the only remaining airline hedging more than 50% of its expected fuel expenses. Further, 11 of the 16 remaining airlines hedge less then 25% of their expected fuel expenses.

Fig. 3 shows the time series of both fuel prices and the fraction of fuel expenses hedged. Fuel cost per gallon falls 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 hedging levels shown in Table 2 and Figs. 2 and 3 could seem low in light of the fact that fuel expenses represent a significant fraction of operating expenses and, given the volatility of oil prices, a significant source of cash flow risk for airlines. That said, a quantitative version of the model would be required to assess whether the limited extent of risk management in the data is consistent with our theory.

(*footnote continued*)
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."

[12] The airline reports being a party to more than six hundred 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 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."

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 airline assets in millions of 2005 US dollars across the sample period. Fuel pass through takes on the value one for airlines that at some point in the sample have a separate entity that bears the risk of fuel price movements.

Airline	First year	Last year	Average assets	Fuel pass through
AMR Corp./DE	1996	2009	28,370	0
Delta Air Lines Inc.	1996	2009	24,815	0
United Continental Hldgs Inc./UAL Corp.	1996	2009	22,111	0
Northwest Airlines Corp.	1996	2007	13,860	0
Continental Airlines Inc. - CL B	1996	2009	10,233	0
Southwest Airlines	1996	2009	10,092	0
US Airways Group Inc. – Old	1996	2004	9,069	0
US Airways Group Inc./America West Holdings Corp.	1996	2009	3,666	0
Jetblue Airways Corp.	2000	2009	3,350	0
Alaska Air Group Inc.	1996	2009	3,251	0
Republic Airways Hldgs Inc.	2002	2009	2,055	1
Skywest Inc.	1996	2009	1,883	1
Airtran Holdings Inc./Valujet Inc.	1996	2009	1,014	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	0

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 Securities and Exchange Commission filings. Other fuel variables are from Capital IQ. Net worth, credit rating, and operating income data are from Standard & Poor's Compustat. The core Compustat variables are constructed as follows: net worth (bv) $B: SEQ (Stockholders' Equity – Total) divided by 1000; net worth to total assets (bv): SEQ divided by AT (Assets – Total); net worth (mv) $B: AT plus PRCC_F (Price Close – Annual – Fiscal) times CSHO (Common Shares Outstanding) minus CEQ (Common/Ordinary Equity – Total) minus TXDB (Deferred Taxes (Balance Sheet)) minus LT (Liabilities – Total); net worth to total assets (mv): net worth (mv) $B divided by (AT plus PRCC_F times CSHO minus CEQ minus TXDB); operating income to lagged assets ratio: OIBDP (Operating Income Before Depreciation) divided by 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.

Statistic	*N*	Mean	Standard deviation	Percentile 10th	50th	90th
Fraction of next year's fuel expenses hedged	244	0.381	0.388	0.000	0.240	1.000
Fraction of next year's fuel expenses hedged for airlines without fuel pass through	184	0.199	0.238	0.000	0.115	0.500
Fuel pass through agreement in place	270	0.222	0.417	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

4.4. Measuring net worth

A key prediction of the theory in Section 3 is that firms that have low current net worth 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

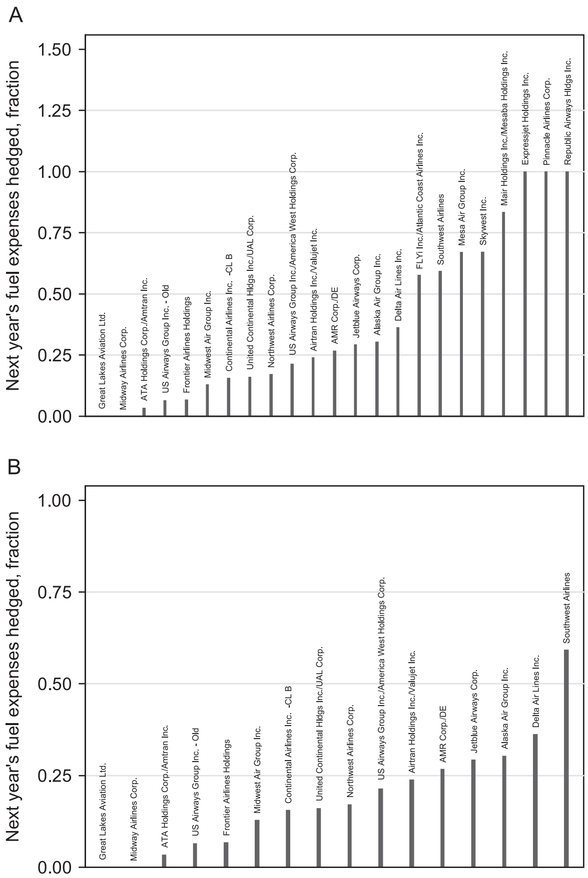

Fig. 2. Fuel expense hedging by airline. This figure presents the average fraction of next year's fuel expenses hedged for each airline. The average is computed over all years the airline is in the sample. Panel A includes the full sample. Panel B excludes any airline that has a fuel pass through agreement at any point in the sample.

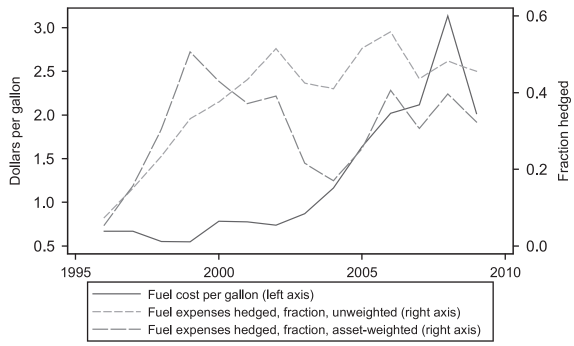

Fig. 3. Fuel expense hedging in the time series. This figure presents the average fuel cost per gallon across airlines by year and the average fraction of next year's fuel expenses hedged across airlines by year. The longer dashed line represents the weighted average of next year's fuel expenses hedged when the weights are total assets of the airline.

model that we take to the data is that in an environment in which collateral constraints apply to both external finance and risk management activity, risk management is lower when the marginal value of net worth today is very high. And the marginal value of current net worth is very high when the level of current net worth 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 regard to net worth, and hence the marginal value of net worth is high when net worth is low. The state variable is net worth, not the amount of collateral itself, as the amount of collateral is endogenously determined by the investment policy, given net worth.

Net worth in our model is the sum of current cash flow, the value of capital net of debt, plus the payoff of any contingent claims used to hedge. We use a total of five variables as the empirical analogs of net worth, the state variable in the model. Close analogs 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. In practice, the production function could 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 also use 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 five measures of net worth.

In the model, net worth is the predetermined state variable and variation in net worth determines variation in hedging decisions. When testing this prediction in the data, a concern is that omitted variables could be simultaneously driving net worth and hedging activity. While the empirical results are consistent with our interpretation of this correlation, causality could still be a concern. One way to address this concern is to isolate a precise source of variation in net worth through a two-stage least squares estimation.

In determining an instrument for net worth, our primary goal is to stay as close to the theory as possible. In the theory, net worth is determined by two exogenous factors: input prices and productivity. Input prices, that is, fuel prices, likely affect all airlines in a similar manner, and so we focus on productivity as the main source of idiosyncratic variation in net worth. We measure productivity using observed operating income. In Section 5.3, we report specifications in which we instrument for net worth using operating income. The two-stage least squares estimation yields qualitatively similar results.

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 a strong positive correlation exists between airlines' fuel price hedging and net worth both in the cross section and within airlines over time. Importantly, our data allow us to study the within-firm

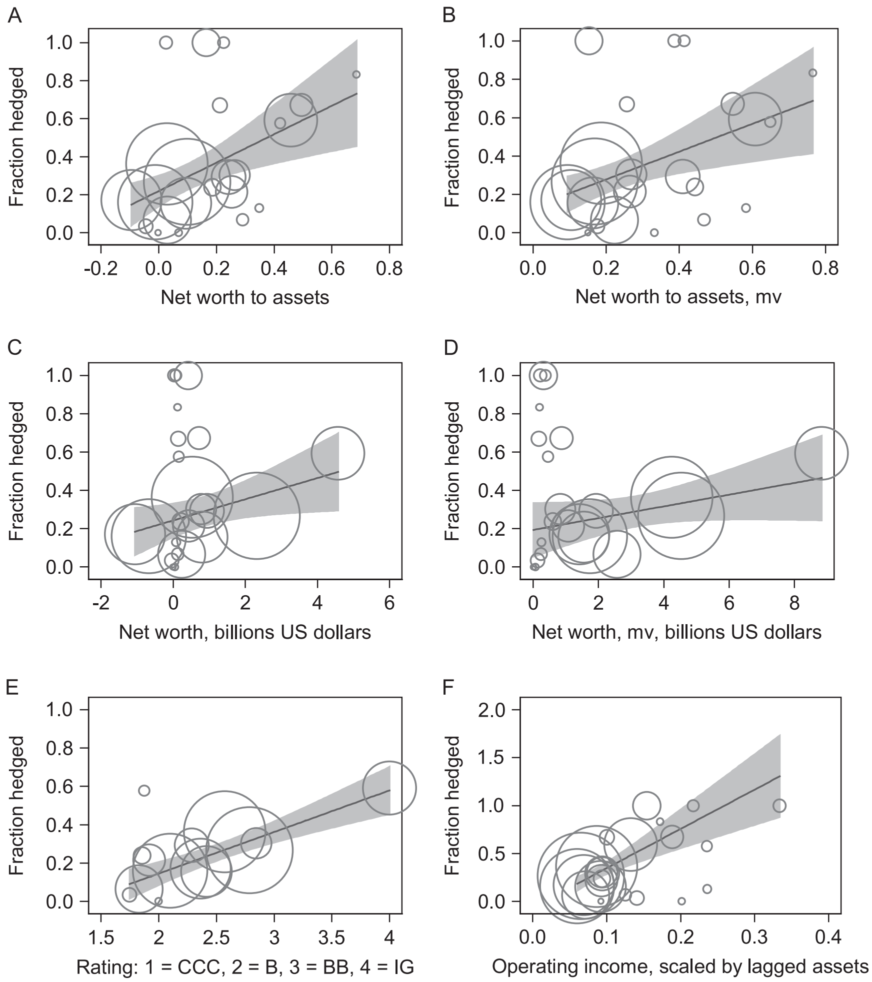

Fig. 4. Fuel expense hedging and net worth: cross-sectional evidence. This figure presents cross-sectional scatter plots of the fraction of next year's fuel expenses hedged and measures of net worth in the current year. All variables are averaged across years for each firm. The size of the circles reflects total assets, and the regression lines are based on (firm-mean) asset-weighted regressions. Panel A: Net worth to assets; Panel B: Net worth (mv) to assets; Panel C: Net worth; Panel D: Net worth (mv); Panel E: Credit rating; and Panel F: Operating income to assets.

variation of hedging and net worth separately, in contrast to most previous studies.

5.1. Hedging and net worth: cross-sectional evidence

Fig. 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 Fig. 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 in which the regression is weighted by total assets of the firm.

We focus on regressions that are weighted by total assets in our study, which is justified given evidence in Appendix C 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). For completeness, we also report the OLS estimates, which are similar, in our main tables.

Across all five measures, a strong positive correlation emerges between the measure of net worth and the fraction of next year's expected fuel expenses hedged. What could appear to be outliers in these specifications are generally regional airlines with code-sharing agreements that include fuel pass through agreements, which we code as hedging 100%. These airlines tend to have low net worth, and yet one could interpret their fuel pass through agreements as a decision to hedge. However, as we argue above, it is questionable whether the fuel pass through agreements of regional airlines should be interpreted as an independent decision to hedge. In Appendix B, we provide support for the view that such agreements are part of a larger wet lease type transaction and not a separate hedging decision.[13]

In Panel F of Fig. 4, we show a strong positive correlation between hedging and operating income scaled by

[13] Regressions excluding airlines with such agreements yield similar results and are reported in Section 7.

lagged assets. In the instrumental variables estimation reported below, we use operating income scaled by lagged assets as an instrument for net worth. Therefore, Panel F can be interpreted as the reduced form version of the two-stage least squares estimate.

Panel A of Table 3 presents the regression coefficients that correspond to the scatter plots in Fig. 4. Despite the small sample size, a robust and statistically significant positive correlation exists between net worth and hedging activity. In terms of magnitudes, the estimate in Column 2 implies that a 1 standard deviation increase in the market net worth to assets ratio implies a 0.5 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 22% 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. No additional decline in hedging is seen when the firm is further downgraded to CCC+ or worse. The OLS estimates reported in Panel B are similar in magnitude, although the significance of some of the coefficient estimates is somewhat reduced.

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, unlike most previous studies. As Panel A shows, the fixed effects estimates are positive and statistically different from 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 similar to the airline mean regressions in Table 3 which exploit only variation between airlines. 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. Again, the OLS estimates are very similar in magnitude and significance for all variables except net worth to total assets (see Panel B).

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

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. The dependent variable is the firm mean of the fraction of next year's fuel expenses hedged. Panel A presents estimates from weighted least squares (WLS) regressions that are weighted by total assets of the airline-year observation; Panel B, estimates from unweighted ordinary least squares (OLS) regressions. All regressions include a constant. Standard errors are in parenthesis. Table 2 contains detailed definitions of the variables. Coefficients that are statistically different from zero at the 1%, 5%, and 10% significance level are denoted by **, *, +, respectively.

	Net worth to assets (bv) (1)	Net worth to assets (mv) (2)	Net worth (bv), $B (3)	Net worth (mv), $B (4)	Credit rating (5)	Credit rating dummies (6)
Panel A: WLS estimation						
Measure of net worth	0.749**	0.725**	0.055*	0.031	0.217**	
	(0.123)	(0.103)	(0.020)	(0.018)	(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)
Number of observations	23	23	23	23	14	14
R-squared	0.358	0.317	0.199	0.127	0.748	0.798
Panel B: OLS estimation						
Measure of net worth	0.746**	0.656*	0.044	−0.003	0.174**	
	(0.216)	(0.280)	(0.030)	(0.028)	(0.055)	
Rating = BB−, BB, or BB+						−0.321**
						(0.080)
Rating = B−, B, or B+						−0.397**
						(0.110)
Rating = CCC+ or worse						−0.485
						(0.274)
Number of observations	23	23	23	23	14	14
R-squared	0.187	0.141	0.020	0.000	0.346	0.379

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. The dependent variable is the fraction of next year's fuel expenses hedged. Panel A presents estimates from weighted least squares (WLS) regressions that are weighted by total assets of the airline-year observation; Panel B, estimates from unweighted ordinary least squares (OLS) regressions. All regressions include year fixed effects. Standard errors are in parenthesis and are clustered at the airline level. Table 2 contains detailed definitions of the variables. Coefficients that are statistically different from zero at the 1%, 5%, and 10% significance level are denoted by **, *, +, respectively.

	Net worth to assets (bv) (1)	Net worth to assets (mv) (2)	Net worth (bv), \$B (3)	Net worth (mv), \$B (4)	Credit rating (5)	Credit rating dummies (6)
Panel A: WLS estimation						
Measure of net worth	0.383*	0.673*	0.020**	0.038**	0.176**	
	(0.139)	(0.271)	(0.005)	(0.010)	(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)
Number of observations	242	240	244	240	145	145
R-squared	0.656	0.664	0.665	0.691	0.645	0.647
Panel B: OLS estimation						
Measure of net worth	0.041	0.097	0.032**	0.052**	0.185**	
	(0.096)	(0.212)	(0.007)	(0.009)	(0.030)	
Rating = BB−, BB, or BB+						−0.266**
						(0.082)
Rating = B−, B, or B+						−0.371**
						(0.069)
Rating = CCC+ or worse						−0.614**
						(0.114)
Number of observations	242	240	244	240	145	145
R-squared	0.698	0.695	0.706	0.731	0.609	0.618

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 dependent and independent variables are first differenced. The dependent variable is the first difference of the fraction of next year's fuel expenses hedged. Panel A presents the estimates from weighted least squares (WLS) regressions that are weighted by total assets of the airline-year observation; Panel B, the estimates from unweighted ordinary least squares (OLS) regressions. All regressions include year fixed effects. Standard errors are in parenthesis and are clustered at the airline level. Table 2 contains detailed definitions of the variables. Coefficients that are statistically different from zero at the 1%, 5%, and 10% significance level are denoted by **, *, +, respectively.

	ΔNet worth to assets (bv) (1)	ΔNet worth to assets (mv) (2)	ΔNet worth (bv), \$B (3)	ΔNet worth (mv), \$B (4)	ΔCredit rating (5)
Panel A: WLS estimation					
Measure of net worth	−0.137	0.623+	−0.008	0.046+	0.136*
	(0.198)	(0.316)	(0.015)	(0.027)	(0.052)
Number of observations	210	208	212	208	125
R-squared	0.228	0.260	0.227	0.279	0.288
Panel B: OLS estimation					
Measure of net worth	0.117	0.309+	−0.005	0.041*	0.161**
	(0.144)	(0.175)	(0.019)	(0.017)	(0.048)
Number of observations	210	208	212	208	125
R-squared	0.080	0.094	0.077	0.101	0.206

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. The first-difference estimates are similar to the fixed effects estimates for all of the measures of net worth except for the book value for both the WLS and OLS estimation. The estimates for the book value are slightly negative, but the implied magnitude is small and not significant. The estimates for Columns 2, 4, and 5 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 3–5 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. Because 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.

5.3. Instrumental variables estimates

In Table 6, we present two-stage least squares estimates using operating income as an instrument for firm net worth. In the model, variation in productivity is the primary source of idiosyncratic variation in net worth. The idea behind using operating income as an instrument is that some variation in operating income cannot be predicted and is, therefore, close to random in its effect on net worth.

For completeness, Panel A presents the results from pooled cross section time series regressions, Panel B presents estimates using firm fixed effects, and Panel C presents estimates using first differences. However, in our view, the first-difference specification is the most likely to capture exogenous variation in net worth that comes from random productivity shocks. For example, in first differences, operating income scaled by lagged assets is almost completely serially uncorrelated. In other words, the lagged shock to operating income does not predict the current shock to operating income.

Column 1 of each panel presents the reduced form relation between hedging and the instrument. In all three specifications, a positive correlation exists between hedging and operating income. The relation is statistically significant at the 5% level in both the pooled and the fixed effects regressions, and the relation has a p-value of 0.11 in the first-differences specification.

Columns 2 and 3 present the first stage using the net worth to asset ratio, both in book and market value terms. A strong positive relation exists between operating income and net worth. In the pooled regressions, operating income and the year fixed effects explain 41% and 50% of the variation in book and market net worth measures, respectively. The incremental increase due to operating income above the year fixed effects is 25% and 32% for book and market net worth, respectively. In other words, just as in the model, variation in operating income explains a large fraction of the variation in net worth.

The second stage estimates across all specifications show qualitatively similar results to the weighted least squares results in Tables 3–5. Net worth, instrumented with operating income, has a strong, positive relation with

Table 6

Fuel expense hedging and net worth: instrumental variables.

This table presents coefficient estimates of instrumental variables specifications in which operating income to lagged assets is used as an instrument for firm net worth. Column 1 presents the reduced form relation between hedging and operating income. Columns 2 and 3 present the first stage coefficients, and Columns 4 and 5 the two-stage least squares estimates. Panel A presents estimates of pooled cross section time series regressions; Panel B, estimates of airline fixed effect regressions; and Panel C, estimates of first-difference regressions. All regressions are weighted by total assets of the airline-year observation and include year fixed effects. Standard errors are in parenthesis and are clustered at the airline level. Table 2 contains detailed definitions of the variables. Coefficients that are statistically different from zero at the 1%, 5%, and 10% significance level are denoted by **, *, +, respectively.

	Fraction of fuel expenses hedged	Net worth to assets (bv)	Net worth to assets (mv)	Fraction of next year's fuel expenses hedged	
	(1)	(2)	(3)	(4)	(5)
Panel A: Pooled cross section time series regressions					
Operating income to lagged assets	2.842** (0.504)	2.296** (0.542)	2.111** (0.648)		
Net worth to total assets (bv)				1.308** (0.198)	
Net worth to total assets (mv)					1.339** (0.325)
Number of observations	240	260	260	240	240
R-squared	0.417	0.413	0.506	0.181	0.315
Panel B: Airline fixed effects					
Operating income to lagged assets	1.246* (0.505)	0.726+ (0.354)	1.176** (0.215)		
Net worth to total assets (bv)				1.433** (0.408)	
Net worth to total assets (mv)					1.053* (0.421)
Number of observations	240	260	260	240	240
R-squared	0.650	0.629	0.854	0.422	0.646
Panel C: Airline first differences					
Operating income to lagged assets	0.942 (0.564)	0.454 (0.350)	0.488** (0.082)		
Net worth to total assets (bv)				1.454 (0.879)	
Net worth to total assets (mv)					1.852+ (1.077)
Number of observations	208	237	237	208	208
R-squared	0.252	0.299	0.328	0.092	0.092

hedging. The magnitude of the coefficient is larger in the two-stage least squares estimation relative to the weighted least squares estimates. This might be because the instrument reduces measurement error in net worth or because sources of variation in net worth unrelated to productivity variation might not be able to explain hedging behavior as well.

While the first-difference specifications are only marginally significant, the point estimates are very similar to the estimates from the pooled and airline fixed effects regressions. The first-difference instrumental variables estimates in Columns 4 and 5 have p-values of less than 0.12. This is comforting as shocks to operating income as captured in the first-difference specification are more likely to reflect random productivity shocks as in the model.

6. Hedging around distress

Our theory predicts that severely constrained firms might not hedge at all. In this section, we show 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. We are the first, to the best of our knowledge, to show the remarkable dynamics of corporate risk management around financial distress.

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" (p. 715). However, airlines in distress also consistently emphasize the importance of preserving cash and internal resources. 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 7 lists the ten instances of distress in our sample. Both America West Holdings Corp. and US Airways Group Inc. were downgraded to CCC+ or worse in 2001. US 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 clustered in time—two occur in 2001, three in 2004, two in 2008, and one each in 2002, 2003, and 2005.

Panel A of Fig. 5 shows the average fraction of next year's fuel expenses hedged in the two years before

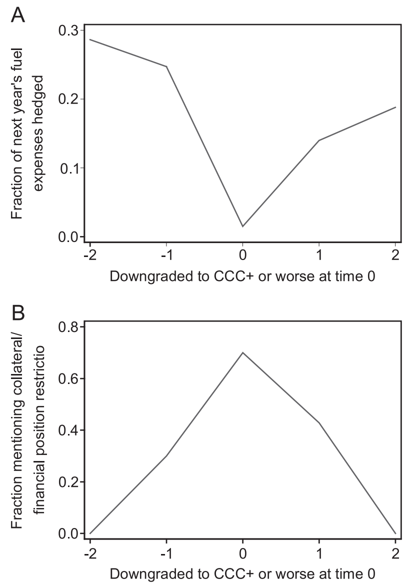

Fig. 5. Fuel expense hedging around distress. This figure provides evidence on fuel expense hedging around distress, where an airline is defined to be in distress when it is rated CCC+ or worse or, when unrated, when it is in bankruptcy. Panel A shows the fraction of next year's fuel expenses hedged 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.

through the two years after entering distress for the ten airlines that 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 7, 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 8. Of the ten instances of distress, only seven result in bankruptcy. As firms approach bankruptcy, hedging drops substantially and, in fact, a significant drop occurs as early as two years before the airline enters bankruptcy. This suggests that entering distress, not bankruptcy per se, is relevant for the drop in hedging.

The evidence in Table 7 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

Table 7
Fuel expense hedging around distress.

This table presents evidence on fuel expense hedging and distress, in which distress is defined as 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. The dependent variable is the fraction of next year's fuel expenses hedged. Column 2 includes airline fixed effects. All regressions are weighted by total assets of the airline-year observation. All regressions include year fixed effects. Standard errors are in parenthesis and are clustered at the airline level. Coefficients that are statistically different from zero at the 1%, 5%, and 10% significance level are denoted by **, *, +, respectively.

Panel A: Sample of distressed airlines

Airline	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

Year relative to distress	Weighted least squares (1)	Fixed effects (2)
Two years before distress	−0.223	−0.140+
	(0.132)	(0.080)
One year before distress	−0.274+	−0.127
	(0.144)	(0.092)
Year entering distress	−0.526**	−0.386**
	(0.100)	(0.090)
One year after distress	−0.421**	−0.228*
	(0.121)	(0.108)
Two years after distress	−0.358**	−0.177+
	(0.100)	(0.093)
Number of observations	244	244
R-squared	0.228	0.711

as our model predicts, because they would otherwise be forced to downsize even more. In Section 6.2, 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 to preserve collateral and internal funds. For the five years around distress for these ten airlines, we read all mentions of fuel price hedging in the 10-K SEC filings of the airline. Panel B of Fig. 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 its 2004 10-K filing, it discloses that “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 its financial condition when discussing its jet fuel hedging program.

America West Airlines provides a similar explanation for cutting its hedging program. From 1998 to 2000, the airline is rated B+ and hedges between 12% and 35% of its expected fuel expenses. In 2001, the airline is downgraded to CCC− and cuts its hedging to just 3% of expected fuel expenses. Its 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. Its average book equity to assets ratio is 0.30 and its credit rating is BBB−. During this period, AMR Corporation hedges between 40% and 50% of its expected jet fuel expenses and never mentions its financial condition or liquidity needs in its 10-K filing when discussing its jet fuel hedging program. AMR

Corporation receives a significant negative shock to its balance sheet strength in 2001 due to the September 11 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 zero. The extent of its hedging declines considerably to an average of only 11%. Further, in every year after 2001, AMR Corporation notes in its 10-K filing that a further deterioration in its 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" (p. 720). 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[14]" (p. 727). Perhaps the strongest evidence comes from their analysis of fuel price hedging by airlines near bankruptcy (p. 715):

> 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.

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 we 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 9 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 could 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 Fig. 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 Fig. 3 shows, jet fuel prices fall in our sample from 1996 to 1998, from 2001 to 2002, and in 2009. We reestimate the cross-sectional regressions for each oil price regime and present the estimates and 95% confidence intervals in Fig. 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). 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, a strong positive correlation exists 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

[14] See the 2004 Annual Report of Delta Air Lines, p. F-22.

Table 8
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. The dependent variable is the fraction of next year's fuel expenses hedged. Column 2 includes airline fixed effects. All regressions are weighted by total assets of the airline-year observation. All regressions include year fixed effects. Standard errors are in parenthesis and are clustered at the airline level. Coefficients that are statistically different from zero at the 1%, 5%, and 10% significance level are denoted by **, *, +, respectively.

Panel A: Sample of airline bankruptcies

Airline	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

Year relative to bankruptcy	Weighted least squares (1)	Fixed effects (2)
Two years before bankruptcy	−0.351**	−0.268**
	(0.124)	(0.067)
One year before bankruptcy	−0.450**	−0.279*
	(0.090)	(0.102)
Year filing for bankruptcy	−0.563**	−0.384**
	(0.098)	(0.105)
One year after bankruptcy	−0.319*	−0.197
	(0.117)	(0.143)
Two years after bankruptcy	−0.379**	−0.236+
	(0.108)	(0.118)
Number of observations	243	243
R-squared	0.210	0.703

influential for the results. We emphasize that the airline fixed effects and first-difference specifications presented above considerably mitigate this concern. Because 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 10, 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 typically smaller regional carriers that limit their effect on the estimates from our asset-weighted regressions.[15] Estimates from specifications that exclude airlines with fuel pass through agreements at any point in the sample, reported in Table 11, are 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 Sharpe and Nguyen, 1995; Eisfeldt and Rampini, 2009; Rampini and Viswanathan, 2013; Rauh and Sufi, 2012) and for airlines in particular (see Benmelech and Bergman, 2008; Gavazza, 2010, 2011).[16] We report specifications that adjust total assets for leased capital in the denominator of our measures of net worth in Table 12. The lease adjustment amounts to capitalizing the value of operating leases as in Rampini and Viswanathan (2013) (Panel A) and Rauh and Sufi (2012) (Panel B). These specifications are moreover weighted by total lease adjusted assets. The results are very similar and, in fact, often stronger.[17]

[15] For a discussion of the nature of fuel pass through agreements and an interpretation of airlines with such agreements as wet lease companies see Section 4.1 and Appendix B.

[16] Benmelech and Bergman (2009) examine the central role of aircraft as collateral in airline finance.

[17] Financial constraints can also affect the vintage of capital that firms deploy. Eisfeldt and Rampini (2007) argue that used capital is cheaper up front but requires more maintenance later on, making it attractive to financially constrained firms. Empirically, they find that the fraction of investment in used capital is substantially higher for financially constrained firms in US census data. Using international data on airlines, Benmelech and Bergman (2011) show that airlines in countries with better creditor protection operate newer aircraft. Because older

Table 9
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 as those that are either rated CCC+ or worse or are in bankruptcy. All regressions are weighted by total assets of the airline-year observation. Standard errors are in parenthesis. Table 2 contains detailed definitions of the variables. Coefficients that are statistically different from zero at the 1%, 5%, and 10% significance level are denoted by **, *, +, respectively.

Specification	Net worth to assets (bv) (1)	Net worth to assets (mv) (2)	Net worth (bv), $B (3)	Net worth (mv), $B (4)	Credit rating (5)	Operating income to lagged assets (6)
Cross section, firm-mean	0.984**	0.708**	0.068**	0.031	0.254**	3.774**
	(0.108)	(0.121)	(0.022)	(0.018)	(0.030)	(0.956)
Airline fixed effects	0.392*	0.502+	0.018*	0.035**	0.154**	0.742*
	(0.152)	(0.248)	(0.007)	(0.006)	(0.032)	(0.350)
Airline first differences	0.797+	0.508	0.095*	0.040	0.185*	0.838
	(0.416)	(0.404)	(0.039)	(0.032)	(0.076)	(0.620)

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 could 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. Such firms could prefer to bet on drops in fuel prices rather then hedge against fuel price increases. This hypothesis implies that firms close to bankruptcy or liquidation engage in speculation or at least abstain from hedging (see Leland, 1998).

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 airlines in our sample explicitly state that they never use derivatives for speculation or trading purposes. Southwest Airlines, for example, states that it “[does] 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 three 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 16 airlines without fuel pass through agreements, 12 airlines (75%) explicitly state they do not use derivatives for trading or speculative purposes. The other airlines could 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 9). 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, 2013). 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 its 2005 10-K, Delta Air Lines states: “[T]he 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. … [W]e received approval of the Creditors Committee to hedge up to 50% of our estimated 2006 aggregate fuel consumption.” Similarly, in its 2002 10-K, United Airlines writes that “[t]he 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

(*footnote continued*)
aircraft are less fuel efficient, financially constrained airlines operating such aircraft should be more exposed to the price of jet fuel, raising the benefit of fuel price risk management all else equal. This effect must be overwhelmed by the trade-off between financing and risk management, as more constrained airlines hedge less in the data.

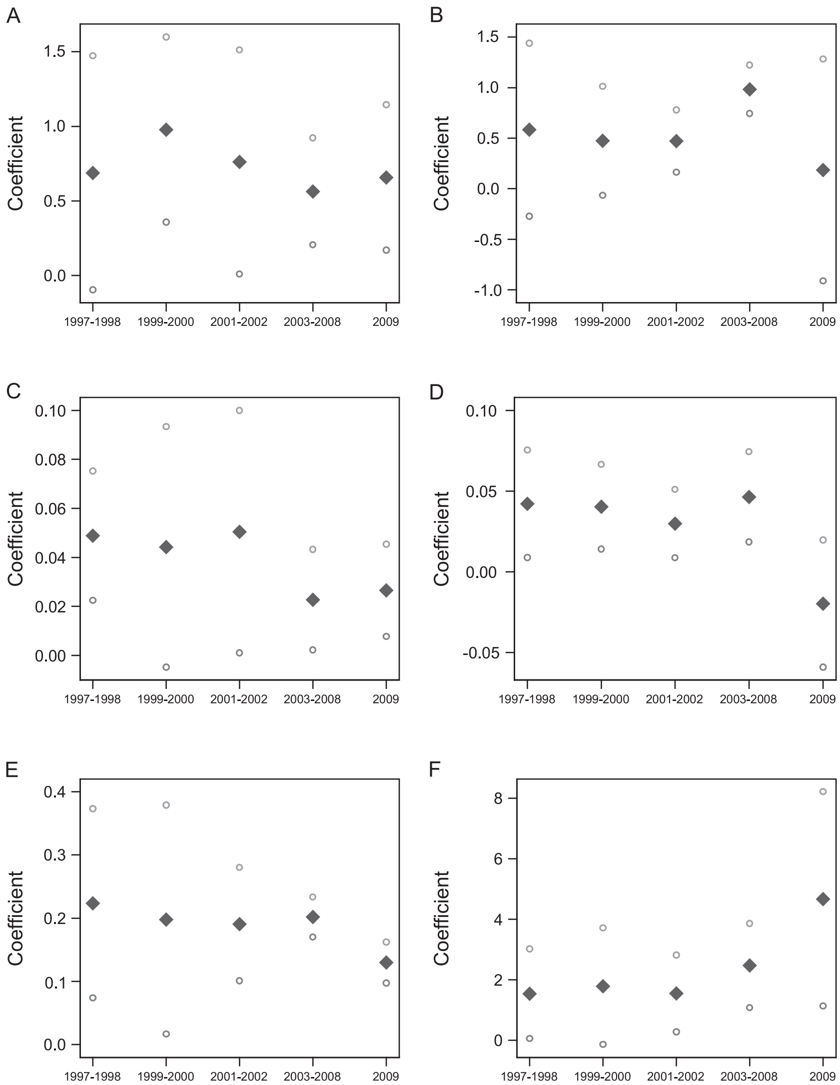

Fig. 6. Fuel expense hedging and net worth across oil price regimes. For each measure of net worth, this figure presents coefficient estimates and 95% confidence intervals from cross-sectional regressions during different oil price regimes. From the periods 1997 to 1998, 2001 to 2002, and 2009, oil prices fell. For the periods 1999 to 2000 and 2003 to 2008, oil prices increased. All regressions are clustered at the airline level. Panel A: Net worth to assets; Panel B: Net worth (mv) to assets; Panel C: Net worth, billions US dollars; Panel D: New worth (mv), billions US dollars; Panel E: Credit rating; and Panel F: Operating income.

that the distressed firms engage in risk shifting/asset substitution of any kind" (p. 1445). 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" (p. 2689).

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 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 argue. However, our data constitute a panel and provide information on both the intensive and extensive margin of hedging instead of on the extensive margin only; that is, they exploit the variation in the fraction of fuel expenses hedged. 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.

Table 10
Fuel expense hedging and net worth excluding Southwest Airlines.

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. Standard errors are in parenthesis. Table 2 contains detailed definitions of the variables. Coefficients that are statistically different from zero at the 1%, 5%, and 10% significance level are denoted by **, *, +, respectively.

Specification	Net worth to assets (bv) (1)	Net worth to assets (mv) (2)	Net worth (bv), $B (3)	Net worth (mv), $B (4)	Credit rating (5)	Operating income to lagged assets (6)
Cross section,	0.670**	0.653*	0.029	0.001	0.198**	3.645**
firm-mean	(0.212)	(0.232)	(0.022)	(0.026)	(0.061)	(0.922)
Airline fixed	0.286*	0.464	0.018**	0.030*	0.175**	1.332*
effects	(0.114)	(0.274)	(0.004)	(0.012)	(0.034)	(0.513)
Airline first	−0.171	0.451	−0.015	0.033	0.141*	1.380**
differences	(0.218)	(0.339)	(0.013)	(0.027)	(0.056)	(0.450)

Table 11
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. Standard errors are in parenthesis. Table 2 contains detailed definitions of the variables. Coefficients that are statistically different from zero at the 1%, 5%, and 10% significance level are denoted by **, *, +, respectively.

Specification	Net worth to assets (bv) (1)	Net worth to assets (mv) (2)	Net worth (bv), $B (3)	Net worth (mv), $B (4)	Credit rating (5)	Operating income to lagged assets (6)
Cross section,	0.646**	0.678**	0.063**	0.053**	0.221**	3.582*
firm-mean	(0.185)	(0.131)	(0.019)	(0.007)	(0.016)	(1.639)
Airline fixed	0.405*	0.848**	0.020**	0.037**	0.175**	1.559*
effects	(0.154)	(0.232)	(0.005)	(0.011)	(0.029)	(0.651)
Airline first	−0.119	0.671+	−0.007	0.041	0.134*	1.079
differences	(0.234)	(0.362)	(0.010)	(0.025)	(0.053)	(0.796)

Table 12
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 eight times rental expense (see Rampini and Viswanathan, 2013) and in Panel B as in Rauh and Sufi (2012). All regressions are weighted by total lease adjusted assets of the airline-year observation. Standard errors are in parenthesis. Table 2 contains detailed definitions of the variables. Coefficients that are statistically different from zero at the 1%, 5%, and 10% significance level are denoted by **, *, +, respectively.

Specification	Net worth to assets (bv) (1)	Net worth to assets (mv) (2)	Operating income to lagged assets (3)
Panel A: Lease adjusted assets as in Rampini and Viswanathan (2013)			
Cross section, firm-mean	1.246**	0.939**	5.917**
	(0.181)	(0.148)	(1.834)
Airline fixed effects	0.609**	0.915*	2.420**
	(0.199)	(0.331)	(0.660)
Airline first differences	−0.205	0.951+	1.325
	(0.335)	(0.465)	(0.855)
Panel B: Lease adjusted assets as in Rauh and Sufi (2012)			
Cross section, firm-mean	1.064**	0.799**	2.957*
	(0.172)	(0.134)	(1.344)
Airline fixed effects	0.542*	0.825*	2.238**
	(0.198)	(0.347)	(0.715)
Airline first differences	−0.127	0.757+	2.200**
	(0.307)	(0.413)	(0.738)

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. 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 third 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 9).

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 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 could serve as a starting point for theories of why bundling financing and risk management might 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 could 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 in the context of commodity price risk management. 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.

Appendix A. Proof of Proposition 1

The static profit maximization problem of the firm, given an amount of capital k, is

$$\pi(k) \equiv \max_{x'} \widehat{A}' k^{\widehat{\alpha}} x'^{\phi} - p'x'. \tag{9}$$

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 $\pi(k) = \widehat{A}'^{1/(1-\phi)}(1-\phi)\phi^{\phi/(1-\phi)}p'^{-\phi/(1-\phi)}k^{\widehat{\alpha}/(1-\phi)} = A'k^{\alpha}$ 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. □

Appendix B. Economics of airlines with fuel pass through agreements

In this appendix, we discuss the nature of fuel pass through agreements in more detail. We argue that fuel pass through agreements are but one of many agreements associated with code sharing agreements between regional airlines and major airlines and should not be interpreted as an independent decision to hedge fuel price risk.

Regional carriers often operate flights on behalf of major carriers in a code sharing agreement with a fixed-fee arrangement, in which the major carriers pay the regional carriers a fixed rate per flight. The major airlines are typically responsible for scheduling, pricing, and marketing of such routes and provide the jet fuel. They bear the fuel price risk under a fuel pass through agreement. Much of the regional jet service of major US airlines is provided by regional airlines in this way. The regional airlines in such agreements are essentially wet lease companies. A wet lease is a leasing agreement in which the lessor provides the aircraft, including crew, maintenance, etc., to the lessee. Thus, one could argue that airlines with these types of code sharing agreements associated with fuel pass through agreements are in the leasing industry and should be excluded from the analysis, as we do in our robustness results.[18]

[18] Under this interpretation, spin-offs of regional jet service by distressed airlines amount to sale-and-leaseback transactions.

One empirical result that supports our interpretation of fuel pass through agreements comes from within-firm variation on hedging among firms that ever use a fuel pass through agreement. Seven airlines in our analysis have a fuel pass through agreement at any point in the sample. These seven airlines represent 71 firm-year observations. But these seven airlines do not always have a fuel pass through agreement. For 11 of these firm-year observations, the airlines do not have a fuel pass through agreement. And when these firms do not have a fuel pass through agreement, none of them hedges its fuel exposure at all. This suggests that these airlines are not making an independent decision to hedge jet fuel when they have a fuel pass through agreement. Such agreements are instead part of a broader wet lease transaction with the major carrier.

The example of Atlantic Coast Airlines (ACC), which is in our sample, illustrates this. Through 2003, ACC was a regional carrier for United Airlines and Delta Airlines. According to ACC's 10-K filing, the major carriers were responsible for “route planning, scheduling, pricing, revenue management, revenue accounting and certain marketing functions including advertising and local promotions.” Under these agreements, United and Delta provided fuel and covered any fuel price risk through a fuel pass through agreement. In 2004, ACC split from these agreements with United and Delta and began running its own branded airline called Independence Air, Inc. Independence Air had no direct relation with the former partners. This provides a nice within-firm natural experiment to see whether the previous fuel pass through agreement was an independent decision to hedge fuel prices, or whether the fuel pass through agreement was just one small part of the overall relationship with the major carriers.

The evidence strongly supports the latter. In its first year of independent operations, Independence Air did not hedge any of its fuel exposure. In other words, as soon as ACC started to operate independently and was no longer covered by the fuel pass through agreements with Delta and United, the company was fully exposed to fuel price movements. Fuel prices spiked in 2004 and 2005, and it noted in its 2004 10-K filing:

> The Company's finances have been dramatically affected by record high fuel prices. Recently, Independence Air has purchased fuel at a price of $1.65 per gallon. When Independence Air operations commenced in June 2004, fuel prices were $1.27 per gallon, and the original business plan from June 2004 for Independence Air estimated fuel prices, based on then-prevailing market prices, was at $.90 per gallon. Independence Air estimates that it will consume approximately 100 million gallons of jet fuel in 2005. Independence Air has not hedged fuel costs.

The company ended up filing for bankruptcy in 2005, with high fuel prices playing an important role.

An alternative test is to examine firms that have a fuel pass through agreement with a major carrier, but still have some residual fuel price risk not covered by the fuel pass through agreement. For example, some regional carriers have multiple subsidiaries, some of which have a relation with a major carrier, whereas others do not. Or in other circumstances, the fuel pass through agreement covers only a fraction of all fuel used by the regional carrier.[19]

We searched the 10-K filings directly for the 60 airline-year observations that report a fuel pass through agreement. Of these 60 observations, exactly 50% report that they have some residual fuel price risk not covered by the fuel pass through agreement. And of the 30 observations in which the airlines explicitly state that there is residual fuel price risk remaining, only three report taking efforts to hedge that risk. So 90% of airline-year observations with a fuel pass through agreement and residual fuel price risk beyond the agreement do not hedge the residual fuel price risk.

An example that illustrates this broader pattern is Mesaba Holdings, Inc. In its 2002 10-K filing, the company explains that it has two subsidiaries: Mesaba, which is a regional airline providing flights under an airlines services agreement with Northwest Airlines, and Big Sky, which operates under its own code.

> *Mesaba*: Mesaba has arrangements with Northwest and five fuel suppliers for its fuel requirements. Certain provisions of the Airlink Agreement [with Northwest] protect Mesaba from fluctuations in aviation fuel prices while the Jet Agreement requires Northwest to provide jet fuel, at Northwest's expense, to Mesaba.
>
> *Big Sky*: Big Sky purchases a majority of its fuel under a fuel agreement with Northwest. Big Sky purchases the balance of its fuel under arrangements with two fuel suppliers. None of these arrangements provide [sic] protection from fluctuations in fuel prices.

This example provides further support for our argument that fuel pass through agreements are one part of an overall agreement in which a major carrier covers all costs of a regional carrier operating under its airline code. Fuel pass through agreements do not appear to be independent decisions of regional airlines to hedge fuel price risk.

Appendix C. Weighted least squares 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 heteroskedasticity and if there is a known variable that is a linear function of the degree of heteroskedasticity, weighted least squares with weights being the inverse square root of the known variable is a more efficient estimator than OLS.

Fig. C1 presents evidence that is suggestive of heteroskedasticity of the above form. To produce the figure, we first regress the fraction of next year's expected fuel

[19] In our main data collection, we report the exact fraction of fuel covered by the fuel pass through agreement if it is reported. If it is not reported, we err on the side of caution and report that all fuel is hedged if the firm reports a fuel pass through agreement. This overstates the hedging activity of firms utilizing fuel pass through agreements, because many of these firms report that they have residual fuel price risk (without reporting how much). These firms tend to have low net worth, and so this biases our results away from finding a positive relation between hedging and net worth.

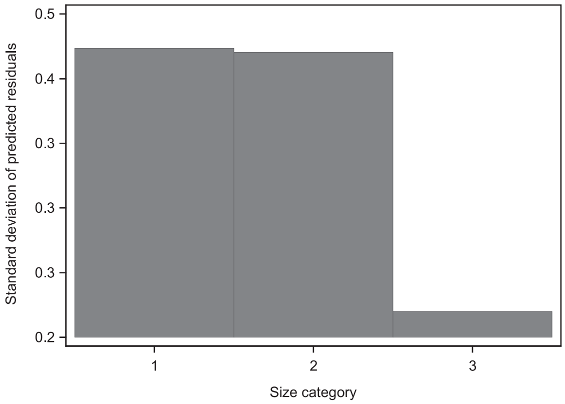

Fig. C1. Heteroskedasticity by size. The figure shows the standard deviation of the predicted residuals (from a regression of the fraction of next year's expected fuel expenses hedged on the market value of net worth to total assets) by the tercile of the book value of assets.

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, a strong negative relation exists between the standard deviation of the predicted residuals and the book value of assets. The pattern in the figure strongly suggests heteroskedasticity and that the heteroskedasticity 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.

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