Corporate Finance Theory - Solution Guide to Final Exam (December 2016)

1. Problem 1

Write 1 to 2 paragraphs for each of the following subquestions. You are welcome to use a limited number of mathematical symbols in your answer, but please do not include any explicit calculations.

(a) Explain intuitively why a high-quality firm has a larger incentive than a low-quality firm to opt for an IPO, relative to an acquisition, in the setting of Bayar and Chemmanur (2011). Discuss how this relates to the 'IPO valuation premium puzzle' described in their paper.

Solution: In the setting of Bayar and Chemmanur (2011), an entrepreneur who opts for an acquisition earns a payoff that is independent of his firm's quality. This is because, by assumption, the acquirer helps the acquired firm compete in the product market, and does so to a larger extent if firm quality is low. In contrast, an entrepreneur who opts for an IPO earns a higher payoff if firm quality is high than if it is low. Intuitively, with an IPO, the entrepreneur cares about the price at which he can issues shares, which depends on investor beliefs about quality, but he also cares about the expected value of the shares that he continues to hold (i.e. his long-term stake in the firm), which depends on actual quality. The expected value of this long-term stake is higher for a high-quality firm than a low-quality firm, one interpretation being that a high-quality firm can better compete in the product market. This in turn pushes a high-quality to firm towards choosing an IPO, relative to a low-quality firm.

The IPO valuation premium puzzle relates to the question of why some entrepreneurs may opt for an acquisition, even though they could instead have chosen an IPO, at what may be a very attractive share price. Bayar and Chemmanur (2011) present a resolution to this puzzle that is closely linked to the issues mentioned above. The IPO share price may be quite high, because investors understand that (in equilibrium) firms that opt for an IPO tend to be of high quality. Low-quality firms may opt for an acquisition, despite the high IPO share price, because they would still retain a long-term stake in the firm following an IPO, and they know that the value of this stake would be low.

(b) Consider the framework of Malenko and Malenko (2015), and suppose that a particular sponsor is never able to provide any operational benefits through LBOs. Describe what this implies about the sponsor's ability to provide financing benefits through LBOs, in a repeated setting, and explain why.

Solution: In Malenko and Malenko (2015), a sponsor that is never able to provide any operational benefits through LBOs will be unable to provide any financing benefits. Sponsors can potentially provide financing benefits if they are able to borrow against their reputation, i.e. again the future profits they expect to earn from subsequent acquisitions. A sponsor that has just made an acquisition and borrowed a large amount knows that if it diverts cash today, rather than pays back creditors as promised, it will be punished in

the credit market tomorrow, and lose part of these future profits. The prospect of this future punishment may be enough to ensure that the sponsor keeps it promise, allowing it to borrow more (and on more favorable terms, i.e. a low interest rate), and thereby offer a financing benefit. However, if the sponsor is never able to provide any operational benefits, this punishment carries no weight. Such a sponsor will not expect any profits in the future - because acquisitions will not take place, or if they do, competition will drive profits down to zero, because this sponsor has no competitive advantage over its rivals. Thus, creditors realize that such a sponsor will have an incentive to divert cash if it takes on high debt. As a result, creditors will not offer the sponsor favorable terms, the sponsor will not borrow a high amount, and will therefore not provide any financing benefit following an acquisition.

(c) Explain intuitively why high debt levels can make it more difficult for a firm to motivate its workers in the framework of Fahn et al. (2014), and describe how this relates to the idea of *commitment*. Choose one other article we have looked at this semester where commitment problems also play a role, and describe the main difference between the commitment problem in that article, and the one in Fahn et al. (2014).

Solution: A central element in Fahn et al. (2014) is that the firm faces a commitment problem relative to its workforce. Specifically, the firm can promise to pay a bonus if a worker exerts high effort (or equivalently shows good performance). But since effort is not verifiable in court, the firm can renege on this promise after effort is chosen, and refuse to pay the bonus. If the worker anticipates that the firm will renege, then she will instead choose low effort. This will in turn reduce firm profits, both because low effort leads to low output, and because it increases the probability of a shock that will lead to firm liquidation. The commitment problem may be less severe in a repeated setting - the firm knows that if it reneges on a promised bonus today, it will be punished by low effort in the future, which increases the firm's incentives to keep its promise. However, high debt can increase the firm's incentive to renege by allowing it to pass part of this future punishment onto creditors. If the firm reneges to the worker, it will still be able to borrow at a favorable rate, as long as it stays solvent (in particular as it cannot commit to reveal to creditors that it has 'cheated' workers). Moreover, if a shock hits and the firm is liquidated, it is creditors who will bear part of these costs. This leads to Fahn et al. (2014)'s conclusion that equity financing (as opposed to debt financing) plays a commitment role.

Commitment problems play a role in a number of other papers we have looked at this semester. Take, for example, Admati et al. (2015)'s analysis of the leverage ratchet effect. There, a firm that borrows from creditors today cannot commit to refrain from taking on more debt from other creditors in the future and then engaging in risk-shifting/asset substitution. As in Fahn et al. (2014), the firm suffers from its commitment problem - in Admati et al. (2015), it is because creditors realize that future firm borrowing will reduce the probability they will be repayed, leading them to charge a higher interest rate. A major difference is that the firm's commitment problem in Admati et al. (2015) relates directly to its borrowing behavior and to creditors, whereas the main commitment problem in Fahn et al. (2014) relates to bonus payments and the firm's relationship with its workers.

2. Problem 2

This question is based on the static framework of DeMarzo et al. (2014), with two differences. First, whereas DeMarzo et al. (2014) consider a single firm, with one owner, one manager, and a safe/risky project, we allow for multiple firms (each with one owner, one manager, and a safe/risky project). We also allow wage payments to each manager to depend on both the cash flows he reports, as well as on the cash flows reported by managers in the other firms. Second, we assume that the state of the world ('Good' or 'Disaster') is unobservable. This implies that the wage a manager receives can only depend on cash flow reports, but not directly on the state.

The text below provides a detailed description of the problem. Keep in mind that, if we set $N = 1$, then this problem description would correspond to the static model of DeMarzo et al. (2014), except that wage payments cannot be conditioned on the realized state. When answering this question, you are expected to explicitly work with, and manipulate, the relevant mathematical expressions.

Consider a setting with $N \geq 1$ firms, and where the state of the world θ is either 'Good' ($\theta = G$) or 'Disaster' ($\theta = D$). Each firm $i \in \{1, 2, \ldots, N\}$ consists of an owner and a manager (both with subscript i). Neither of them observe the state of the world, but they hold the following prior beliefs: $\mathbb{P}(\theta = G) = 1 - \delta$, and $\mathbb{P}(\theta = D) = \delta$, with $0 < \delta < 1$.

The timing of the game is as followed. First, the state of the world is realized. Second, in each firm i, owner i offers a contract $w_i(r_1, \ldots, r_N)$ to manager i. This contract specifies the wage w_i the manager will later receive, conditional on the cash flow he reports, r_i, and the cash flows reported by other managers, $(r_1, \ldots, r_{i-1}, r_{i+1}, \ldots r_N)$ (more details below). Third, manager i observes this contract and chooses a project $p_i \in \{S, R\}$, where S stands for 'Safe' and R stands for 'Risky'. Fourth, the cash flow of this project is realized, which we denote by $Y_i(p_i, \theta)$. Fifth, manager i observes the cash flow $Y_i(p_i, \theta)$ and sends a public report about it, r_i. Sixth, owner i observes the set of reports from all N managers, $(r_1, \ldots, r_N)$, and pays manager i the wage $w_i(r_1, \ldots, r_N)$ specified under the contract. Finally, payoffs are realized and the game ends.

The realized cash flow $Y_i(p_i, \theta)$ can take on one of three values: 1, 0, and $-D < 0$. The probability of these different values depends both on the project $p_i \in \{S, R\}$ chosen by manager i, and on the state $\theta \in \{G, D\}$, in the following way:

Safe Project, Good State:

- $\mathbb{P}(Y_i = 1 | p_i = S, \theta = G) = \frac{\mu}{1-\delta}$
- $\mathbb{P}(Y_i = 0 | p_i = S, \theta = G) = 1 - \frac{\mu}{1-\delta}$
- $\mathbb{P}(Y_i = -D | p_i = S, \theta = G) = 0$

Safe Project, Disaster State:

- $\mathbb{P}(Y_i = 1 | p_i = S, \theta = D) = 0$

- $\mathbb{P}(Y_i = 0 | p_i = S, \theta = D) = 1$
- $\mathbb{P}(Y_i = -D | p_i = S, \theta = D) = 0$

Risky Project, Good State:

- $\mathbb{P}(Y_i = 1 | p_i = R, \theta = G) = \frac{\mu+\rho}{1-\delta}$
- $\mathbb{P}(Y_i = 0 | p_i = R, \theta = G) = 1 - \left(\frac{\mu+\rho}{1-\delta}\right)$
- $\mathbb{P}(Y_i = -D | p_i = R, \theta = G) = 0$

Risky Project, Disaster State:

- $\mathbb{P}(Y_i = 1 | p_i = R, \theta = D) = 0$
- $\mathbb{P}(Y_i = 0 | p_i = R, \theta = D) = 0$
- $\mathbb{P}(Y_i = -D | p_i = R, \theta = D) = 1$

where $0 < \mu < 1 - \delta$, and $0 < \rho < 1 - \delta - \mu$. Conditional on the state and project selection, the realized cash flow for manager i is independent of the realized cash flows of the other managers.

We will assume that manager i must truthfully report the realized cash flow if it is 0 or $-D$, i.e. $r_i = Y_i$ whenever $Y_i \in \{0, -D\}$. However, if the realized cash flow is 1, then manager i can choose to truthfully report, $r_i = Y_i = 1$, or to instead report $r_i = 0$ and divert cash. The manager's private benefit from diverting cash is λ, where $0 < \lambda < 1$.

Payoffs are as follows. If manager i reports truthfully, then his payoff is equal to the wage he receives: $\pi_i^M = w(r_1, \ldots, r_N | r_i = Y_i)$. If manager i does not report truthfully, then his payoff is just the private benefit of diverting cash: $\pi_i^M = \lambda$. (Aside: Formally speaking, it would be more reasonable to assume that this payoff would equal $w_i(r_1, \ldots, r_N | r_i = 0) + \lambda$, hence the private benefit of diverting cash, plus the wage. But we will assume that the payoff is simply $\pi_i^M = \lambda$ if the manager diverts cash, to keep the problem tractable.) The payoff to owner i is equal to the cash flow reported by manager i, minus the wage paid: $\pi_i^O = r_i - w_i(r_1, \ldots, r_N)$. The manager is protected by limited liability, so that wages must be non-negative: $w_i(r_1, \ldots, r_N) \geq 0$, for any vector of reports $(r_1, \ldots, r_N)$. You can also assume that the condition $\delta D - \rho > 0$ holds.

(a) Find the expected cash flows (from an ex ante perspective) generated by the safe project, and compare them to the expected cash flows generated by the risky project. Show which of these expected cash flows is higher (i.e. which project is more efficient).

Solution: The expected cash flow from the safe project is $1(\mu) + 0(1 - \mu) - D(0) = \mu$. *The expected cash flow from the risky project is* $1(\mu + \rho) + 0(1 - \delta - \mu - \rho) - D(\delta) = \mu + \rho - \delta D$. *By assumption, the condition* $\delta D - \rho > 0$ *holds, which implies that the safe project is more efficient.*

We now concentrate on the incentives of the owner and manager in a specific firm i. Suppose that owner i and manager i both expect that managers in all $N-1$ other firms will choose the safe project and truthfully report cash flows. Moreover, suppose that owner i offers manager i the following contract, which we will call 'contract $\mathbb{W}$' : $w_i(r_1,\ldots,r_N)=\lambda$ if $r_i=1$; $w_i(r_1,\ldots,r_N)=w>0$ if $r_1=\ldots=r_N=0$; and $w_i(r_1,\ldots,r_N)=0$ otherwise. That is, if manager i reports a cash flow of 1, then he will receive a wage of λ, no matter what. But if manager i reports a cash flow of 0, then his wage will depend on the other managers' reports. Specifically, manager i will receives a wage of w if all other managers also report zero cash flow, and a wage of 0 if at least one manager $j\neq i$ reports a cash flow of 1. Owner i specifies the exact value of w when offering the contract; our notation reflects the fact that w can be set at any positive value.

(b) Consider, broadly speaking, how the main features of contract $\mathbb{W}$ compare to DeMarzo et al. (2014)'s proposal of how to implement their 'optimal contract conditional on the disaster state' in practice (see Proposition 3, and the subsection on Implementation that immediately follows). Briefly describe the main similarity and the main difference.

Solution: Contract $\mathbb{W}$ rewards manager i in part based on relative performance. Specifically, if the manager reports a cash flow of 0, then he will be paid more if all others report the same cash flow as him, than he will if at least one manager reports a 'better' cash flow (i.e. a cash flow of 1). Relative performance also plays a central role in the proposal of DeMarzo et al. (2014), which argues that an owner could offer its manager out-of-money put options on firms in the same industry, which only become valuable if these other firms fail (and if the manager's firm stays afloat). Hence, a similarity is the idea of payment for relative performance. A difference is that, under contract $\mathbb{W}$, a manager will not be rewarded specifically because others do worse than him (i.e. if other firms "fail" by generating a negative cash flow), but he may instead be punished because others do better than him (i.e. if some other firm generates a positive cash flow, but his firm does not).

(c) Argue that under contract $\mathbb{W}$, manager i always has an incentive to report cash flows truthfully.

Solution: If the manager truthfully reports a cash flow of 1, then he receives a wage of λ with probability one. By assumption, if the manager does not report truthfully, then his payoff is just the private benefit of diverting cash (see the problem description), which is also equal to λ. Hence, the manager has an incentive to report a positive cash flow truthfully, i.e. diverting cash will not increase his payoff.

(d) Show that under contract $\mathbb{W}$, manager i's expected payoff from choosing the safe project is

$$\pi_i^M(S)=\delta w+(1-\delta)\left[\lambda\frac{\mu}{1-\delta}+w\left(1-\frac{\mu}{1-\delta}\right)^N\right]$$

Solution: Conditional on the disaster state, each manager's project generates zero cash flow with probability 1, so manager i receives wage w for sure. Conditional on the good state, manager i's project generates

a cash flow of 1 *with probability* $\frac{\mu}{1-\delta}$*, in which case he receives a wage of* λ*. His project generates zero cash flow with probability* $1-\frac{\mu}{1-\delta}$*, in which case he receives wage* w *if all* $N-1$ *other managers also generates zero cash flow, which occurs with probability* $(1-\frac{\mu}{1-\delta})^{N-1}$*. Thus, conditional on the good state, manager* i*'s expected payoff is* $\lambda(\frac{\mu}{1-\delta})+w(1-\frac{\mu}{1-\delta})^N$*. Since the probability of the good state is* $1-\delta$*, manager* i*'s expected payoff from an ex ante perspective is* $\delta w+(1-\delta)[\lambda\frac{\mu}{1-\delta}+w(1-\frac{\mu}{1-\delta})^N]$*, as required.*

(e) Show that under contract $\mathbb{W}$, manager i's expected payoff from choosing the risky project is

$$\pi_i^M(R)=(1-\delta)\left[\lambda\left(\frac{\mu+\rho}{1-\delta}\right)+w\left(1-\frac{\mu}{1-\delta}\right)^{N-1}\left(1-\left(\frac{\mu+\rho}{1-\delta}\right)\right)\right]$$

Solution: Conditional on the disaster state, the risky project generates cash flow $-D$ *with probability* 1*, so manager* i *receives zero wage for sure. Conditional on the good state, manager* i*'s project generates a cash flow of* 1 *with probability* $\frac{\mu+\rho}{1-\delta}$*, in which case he receives a wage of* λ*. His project generates zero cash flow with probability* $1-\frac{\mu+\rho}{1-\delta}$*, in which case he receives wage* w *if all* $N-1$ *other managers also generates zero cash flow. All these managers have chosen the safe project, so this occurs with probability* $(1-\frac{\mu}{1-\delta})^{N-1}$*, as above. Since the probability of the good state is* $1-\delta$*, manager* i*'s expected payoff from an ex ante perspective is* $(1-\delta)[\lambda\frac{\mu+\rho}{1-\delta}+w(1-\frac{\mu}{1-\delta})^{N-1}(1-\frac{\mu+\rho}{1-\delta})]$*, as required.*

(f) Describe intuitively why manager i's incentive to choose the safe project, relative to the risky project, will increase if the owner sets a larger value of w. Then show explicitly that the manager will choose the safe project if and only if $w\geq w^*$, where

$$w^*=\frac{\lambda\rho}{\delta+\rho(1-\frac{\mu}{1-\delta})^{N-1}}$$

Solution: The manager can only receives wage w *if he obtains an intermediate outcome (i.e. a cash flow of zero). This intermediate outcome is more likely under the safe project than under the risky project. It follows that, holding the project selection of all other managers constant, setting a high value of* w *will increase manager* i*'s incentive to choose the safe project.*

Manager i *will choose the safe project if and only if* $\pi_i^M(S)\geq\pi_i^M(R)$*. Using the expressions in parts (d) and (e), and grouping terms proportional to* w*, yields the equivalent condition*

$$w\left[\delta+(1-\delta)\left(1-\frac{\mu}{1-\delta}\right)^N\right]+(1-\delta)\lambda\frac{\mu}{1-\delta}\geq w\left[(1-\delta)\left(1-\frac{\mu}{1-\delta}\right)^{N-1}\left(1-\left(\frac{\mu+p}{1-\delta}\right)\right)\right]+(1-\delta)\lambda\left(\frac{\mu+\rho}{1-\delta}\right).$$

Further grouping terms involving w *yields*

$$w\left[\delta+(1-\delta)\left(1-\frac{\mu}{1-\delta}\right)^{N-1}\left(1-\frac{\mu}{1-\delta}-1+\frac{\mu+\rho}{1-\delta}\right)\right]\geq(1-\delta)\lambda\frac{\rho}{1-\delta},$$

which simplifies to

$$w\left[\delta+\rho\left(1-\frac{\mu}{1-\delta}\right)^{N-1}\right]\geq\lambda\rho,$$

or equivalently

$$w \geq \frac{\lambda\rho}{\delta + \rho\left(1 - \frac{\mu}{1-\delta}\right)^{N-1}},$$

as required.

(g) Suppose that owner i wants to use contract $\mathbb{W}$ to implement the safe project, but also wants to minimize expected wage payments to the manager while doing so. Explain what value of w the owner should set. That is, what is the optimal value of w (conditional on implementing the safe project) from the owner's perspective?

Solution: The owner must set some $w \geq w^*$ if he wants to implement the safe project, since otherwise the manager should choose the risky project. Moreover, expected wage payments to the manager are strictly increasing in w. It follows that the optimal value of w (conditional on implementing the safe project) is precisely $w = w^*$.

(h) Using (d) and your answer from part (g), write down an explicit expression for expected wage payments to manager i under contract $\mathbb{W}$, with w set at the optimal value from the owner's perspective. Now take the limit as N tends to infinity. What value does the expected wage payments approach in this limit? *Hint: when taking the limit, use the fact that $\mu < 1 - \delta$.*

Solution: Expected wage payments to the manager are given by $\pi_i^M(S)$ from (d) evaluated at $w = w^*$. One way to write this is:

$$\left[\frac{\lambda\rho}{\delta + \rho\left(1 - \frac{\mu}{1-\delta}\right)^{N-1}}\right]\left[\delta + (1-\delta)\left(1 - \frac{\mu}{1-\delta}\right)^{N}\right] + (1-\delta)\lambda\frac{\mu}{1-\delta}$$

As N tends to infinity, $\left(1 - \frac{\mu}{1-\delta}\right)^{N}$ and $\left(1 - \frac{\mu}{1-\delta}\right)^{N-1}$ approach zero, since $\mu < 1-\delta$ implies $1 - \frac{\mu}{1-\delta} < 1$. Thus, in this limit, expected wage payments approach $\frac{\lambda\rho}{\delta}\delta + (1-\delta)\lambda\frac{\mu}{1-\delta} = \lambda(\rho + \mu)$.

(i) Compare the expected wage payments derived in part (h), in the limit as N tends to infinity, to those from Proposition 3 of DeMarzo et al. (2014): $(\mu + \rho)\lambda$. Is one of these expected wage payments higher/lower than the other? Comment on what the intuition is for this result, and what it implies for implementing DeMarzo et al. (2014)'s 'optimal contract conditional on the disaster state' in practice.

Solution: The expected wage payments derived in part (h), for implementing the safe project, are the same as those in Proposition 3 of DeMarzo et al. (2014). Intuitively, as the number of firms becomes large, a situation where all firms (other than firm i) generate zero cash flow becomes a stronger signal of the disaster state. And it is precisely the owner's ability to reward manager i for a cash flow of zero in the disaster state, but not in the good state, in Proposition 3, that helps solve the moral hazard problem.

Notice that expected wage payments of $(\mu + \rho)\lambda$ are smaller than those necessary to implement the safe project if the owner had no information about the state. Thus, both Proposition 3 and the results above

suggest that the ability to condition payments on the disaster state (either directly, through observing the state, or indirectly, through relative performance evaluation) can help the owner, by allowing him to implement the efficient project at relatively low cost. It also means that, in large markets, it may be possible to effectively implement DeMarzo et al. (2014)'s 'optimal contract conditional on the disaster state' by using a relatively simple bonus scheme that works even in situations where no firms actually fail (e.g. because they have all chosen the safe project).

3. Problem 3

Read the news story 'Big Oil Companies Binge on Debt' from the Wall Street Journal (August 24, 2016), the text of which is reproduced following this question. Please discuss which theoretical ideas from the articles seen this semester can generate the most insight into the phenomenon described in the news story (*you can consider, for example, the possible causes of the rise in debt levels described in the story, and/or its possible consequences*). For the theoretical ideas that you mention, comment on whether the key modelling assumptions behind these ideas are plausible in this particular real-life setting. You are welcome to seek out more information about the companies in question.

Solution: There are many possible ways to answer this question. The important thing is to be clear in your argument and to justify your answer. Relevant points may include (but are certainly not limited to) the following:

- *The idea that firm debt levels may increase over time relates to the 'Leverage Ratchet Effect' of Admati et al. (2015).*
- *Admati et al. (2015) argue that increasing debt levels may benefit shareholders, even if they reduce firm value, because costs are passed on to creditors. The news article reports that shareholders for the oil companies in question continue to receive high dividends (at least for the time being), whereas agencies have downgraded the companies' credit ratings.*
- *While agency conflicts may potentially play a role in explaining borrowing behavior, as in Admati et al. (2015), and in many other papers analyzed this semester, the news article suggests another reason may have been crucial in driving up debt: low oil prices.*
- *The news article also suggests that high debt levels may stop the oil companies from investing in new projects. This can be related to the notion of debt overhang, which we saw at certain points throughout the semester. The idea that creditors' unwillingness to lend may hurt firms, and lead to fewer acquisitions, was also found in Malenko and Malenko (2014) and Almeida et al. (2011), but these were quite different settings.*

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http://www.wsj.com/articles/largest-oil-companies-debts-hit-record-high-1472031002

BUSINESS

Big Oil Companies Binge on Debt

Exxon, Shell, BP and Chevron have combined debt of $184 billion amid two-year slump

Pumping jacks at the Chevron section of the Kern River Oil Field near Bakersfield, Calif. Chevron said earlier this year that its higher debt levels were expected. *PHOTO: AGENCE FRANCE-PRESSE/GETTY IMAGES*

By **SELINA WILLIAMS** and **BRADLEY OLSON**
Updated Aug. 24, 2016 6:13 p.m. ET

Some of the world's largest energy companies are saddled with their highest debt levels ever as they struggle with low crude prices, raising worries about their ability to pay dividends and find new barrels.

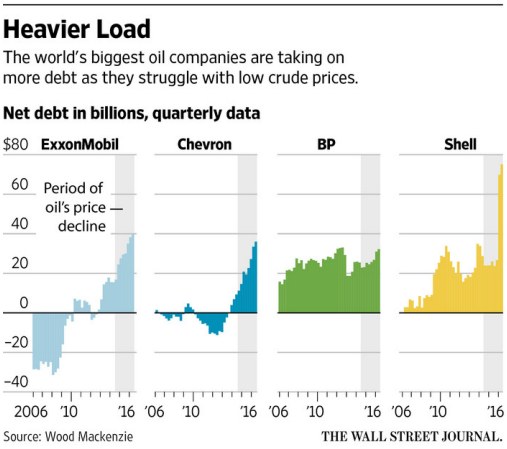
Exxon Mobil Corp., Royal Dutch Shell PLC, BP PLC and Chevron Corp. hold a combined net debt of $184 billion—more than double their debt levels in 2014, when oil prices began a steep descent that eventually bottomed out at $27 a barrel earlier this year. Crude prices have rebounded since, but still hover near $50 a barrel.

The soaring debt levels are a fresh reminder of the toll the two-year price slump has taken on the oil industry. Just a decade ago, these four companies were hauled before Congress to explain "windfall profits" but now can't cover expenses with normal cash flow.

Executives at BP, Shell, Exxon and Chevron have assured investors that they will generate enough cash in 2017 to pay for new investments and dividends, but some shareholders are skeptical. In the first half of 2016, the companies fell short of that goal by $40 billion, according to a Wall Street Journal analysis of their numbers.

"Eventually something will give," said Michael Hulme, manager of the $550 million Carmignac Commodities Fund, which holds stakes in Shell and Exxon. "These companies won't be able to maintain the current dividends at $50 to $60 oil—it's unsustainable."

The debt is piling up despite cuts of billions of dollars on new projects and current operations. Repaying the loans could weigh the companies down for years, crimping their ability to make investments elsewhere and keep pumping ever more oil and gas.



The companies spent more than 100% of their profits on dividends last year. This year, the problem got worse. In the April-to-June period, Exxon paid $3.1 billion in dividends and had just $1.7 billion in net income, according to S&P Global Market Intelligence. Shell paid $1.26 billion in interest in the first half of 2016, compared with $726 million in the same period a year earlier.

"They are just not spending enough to boost production," said Jonathan Waghorn, co-portfolio manager in London at Guinness Atkinson Asset Management Inc. who helps oversee more than $400 million across a range of energy funds, including shares in Exxon, BP, Chevron and Shell.

The oil companies say they have many tools to deploy to help defray debt, including selling assets and offering shareholders more shares instead of a cash dividend, as well as continuing to cut costs. Record-low interest rates are helping ease some of the pain.

They also say the steep levels of debt are temporary as the companies restructure, and the debt will fall when oil prices rise.

'These companies won't be able to maintain the current dividends at $50 to $60 oil—it's unsustainable.'

—Michael Hulme, manager of the Carmignac Commodities Fund

"We are in a transitional stage in 2016," said Shell Chief Executive Ben van Beurden during last month's earnings disclosures. The company reported a rise in net debt to over $75 billion at the end of the second quarter, in large part because of its acquisition of BG Group PLC.

BP has said it expects to be able to pay for its operations, make new investments and meet its dividend at an oil price of between $50 and $55 a barrel next year.

But analysts and investors say the oil slump is making it harder than ever for companies to raise money with asset sales to pay off debt. Handing out more shares to shareholders is only storing up the dividend problem for the future when the companies will need to pay up. Even the boost many companies got from bumper profits from their refining divisions—which tend to do well when prices are low—looks to be coming to an end as a glut of gasoline erodes fuel prices, say investors and analysts.

Still, some funds see BP, Shell, Exxon and Chevron as big enough to weather problems for the next year and a half. Wilmington Trust has reduced its exposure to energy companies it deems more risky in favor of other corporate debt. But the firm remains invested in debt issued by BP, Chevron and Shell

"They're so big, they can diversify, they have more levers to push and pull in terms of shoring up their creditworthiness," said Wilmer Stith, senior fixed-income portfolio manager at Wilmington Trust, which has $73 billion in assets under management.

Only another long period of oil below $40 a barrel would pose a challenge that could prompt dividend cuts, said Iain Reid, senior oil analyst at Macquarie Capital. A Goldman Sachs report this week projected oil prices remaining between $45 and $50 a barrel for much of the next year.

"The question is, can they get through this year and next without doing something radical like cutting dividends?" said Iain Reid, senior oil analyst at Macquarie Capital.

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The rise in net debt has helped push these companies' ratio of net debt to equity to the highest level in years, which influences the ratings given by credit agencies. S&P has already downgraded Shell, Chevron, Exxon and BP, though they all remain highly rated.

Shell's debt-to-equity ratio is at 28% and Chief Financial Officer Simon Henry said last month it could even reach its targeted maximum of 30%. BP's gearing is over 25%, while Chevron's is 20% and Exxon's is around 18%.

By comparison, in 2012, Shell's gearing was around 10%, and Exxon's was 1.2%. Back in 2005, when oil prices were climbing steadily, Exxon had no debt, and its profits were so high that its executives and those from other big oil companies were called to testify in front of the U.S. Senate about their so-called windfall profits.

Chevron's Chief Financial Officer Patricia Yarrington said in April that the company's higher levels of debt were expected. "We could handle that if it's temporary," she said.

Much of the new debt has been in corporate bonds. Exxon, for instance, issued $12 billion in debt in February. Two months later, the company was downgraded by S&P Global Ratings, losing the triple-A credit rating that it had held since 1930.

Exxon Chief Executive Rex Tillerson has assured investors that Exxon remains committed to paying its dividend.

The company has increased shareholder payments for 34 straight years, although those increases have been modest in the past two years. Mr. Tillerson and others have noted that Exxon has the ability to borrow further. If anything, the company has signaled a willingness to go further into debt for strategic opportunities, such as buying assets, including InterOil Corp., a small company focused on gas exports in Papua New Guinea that Exxon agreed to acquire for an estimated $2.5 billion in July

"We're not going to forgo attractive opportunities," said Jeff Woodbury, Exxon's vice president of investor relations, on an investor call last month.

—Heather Gillers in New York contributed to this article.

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Corrections & Amplifications:
In the first half of 2016, the companies fell short of that goal by $40 billion, according to a Wall Street Journal analysis of their numbers. An earlier version of this article incorrectly stated that it was the first half of 2015. Aug. 24, 2016