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The incentive effects of the overlapping project structure in credit markets

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A B S T R A C T

In this theoretical paper, we examine the risk-shifting problem between lenders and a firm running projects in two different environments. In a synchronous environment, the firm introduces two new 2-period projects that both begin and end on the same date and hence have a new start date in odd-numbered periods. In an asynchronous environment, the firm introduces one new 2-period project in every period: This process creates an overlapping structure for the projects. We show that the set of parameters that allow for reputation-supported lending is larger if projects are asynchronous rather than synchronous. The findings can be generalized to other forms of moral hazard.

1. Introduction

Information problems limit the extent of borrowing and cause credit rationing (Allen, 1983; Fishman & Parker, 2015; Fuchs & Skrzypacz, 2015; Stiglitz & Weiss, 1981). Our goal in this paper is to compare the risk-shifting problem under an infinite number of periods in two environments: The firm can introduce new projects either synchronously or asynchronously.

Synchronous refers here to pairs of 2-period projects that both begin and end on the same date and hence have a new start date every other period, while *asynchronous* refers to pairs of 2-period projects that start on alternate dates and hence have a new project start every period. In the asynchronous environment, a firm will select a new project while an existing project is still active. In the synchronous environment, there are no active projects at the time that the firm selects new project types since projects begin and end simultaneously. Decisions in the previous period are thus more likely to affect decisions in the current period in the asynchronous environment, although the direction of the effect is not obvious.

We examine risk-shifting: A firm can invest in riskless good projects (positive NPV) or in bad projects which produce a high output with a low probability (negative NPV). Firms are fully debt-financed. This financing and limited liability may encourage a firm to invest in bad projects because creditors cover any losses, and a costless default is possible for the firm. In those cases, a negative NPV project can be desirable, as when the gains in the favorable state go to the firm (the borrower), while the creditors bear the losses of the unfavorable state.

When a firm chooses the project type, it compares the short-term gain from risk-shifting—a chance for a high profit—with the long-term loss of getting caught for that risk-shifting, which is ostracism from further borrowing. Even if the borrower's project choice is unobservable to lenders, they anticipate the choice correctly and finance projects only if the borrower invests in good projects. We show that risk-shifting may be profitable in the synchronous environment even if it is unprofitable in the asynchronous environment.

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Lenders are aware of this difference and are less inclined to lend in the synchronous environment.

Logically, when introducing asynchronous projects, a firm runs one project in period 1 and two projects in the later periods. The small capacity of period 1 and the profitable growth after the period alleviate the risk-shifting incentives in period 1: the firm will not gamble on the low extra profit of period 1 and take the risk of losing a relatively high future profit if the gamble is unsuccessful and the firm fails. Therefore, the firm chooses a good project in period 1. Owing to this choice, the existing project is good in period 2. This profitable good project alleviates the risk-shifting incentives in period 2. Then, the firm can choose only one new project, that is, gamble only with one project. This choice means that the maximal profit from risk-shifting is low. The firm will not gamble on this low profit and take the risk of losing i) the profit from the existing good project, and ii) the profit from the future periods if the gamble is unsuccessful. This process continues in later periods. In each period, the firm has an existing good project whose risk-free profit alleviates incentives to gamble with a new project. In each period, the firm can gamble only on one new project. Therefore, the maximal profit from the gamble is low.

By contrast, when introducing synchronous projects, a firm starts two new projects in every second year. Since the firm can gamble on two new projects, its maximal profit from the gamble is higher in the favorable states than in the asynchronous environment in which the firm can gamble on only one new project. Moreover, in the synchronous environment, the firm lacks an existing good project whose profit alleviates the risk-shifting incentives.

The central distinction between synchronous and asynchronous environments is that with asynchronous projects, a smaller fraction of the bad-outcome losses can be imposed on the creditors. A firm holding a good project that is considering the negative NPV project must consider the possible losses not only of the negative NPV project, but also of the good assets currently held.

Since introducing asynchronous projects creates an *overlapping structure* for the financed projects, an argument can be made that the incentive problems are slightly lower in the overlapping structure than without it. This effect does not arise in the traditional theories of overlapping generations—for example, Allen and Gale (1997), Diamond (1965), Fulghieri and Rovelli (1998), Niinimäki (2010) and Samuelsen (1958) who examine lifecycle behavior, population growth, and economic growth as well as intertemporal consumption-smoothing and liquidity risk-sharing within and across generations. These features are not present in our model in which the overlapping structure eliminates the option to reallocate the firm's whole wealth in risky assets at the same time and thereby maximize the expected profit from risk-shifting.

We design a dynamic model with wealth-constrained firms. The owners of the firm consume the realized project output at the end of each period and cannot invest personal funds in their firm. Therefore, the firms are fully debt-financed. The sizes of the projects are fixed (one unit). In the first operating period, a firm has one or two projects. Thereafter, the firm runs two projects. Consequently, the firm's size is fixed (two units) after the first period. If a firm behaves well—chooses good projects—it can operate forever because good projects are risk-free. However, the firm does not build a long-term relationship with lenders, because they live only for a period. Instead, the firm makes 1-period loan contracts with lenders who know the repayment history of the firm. Since the choice situation is identical in each period (apart from period 1), the firm faces a succession of identical static contract problems with short-lived lenders in periods $t = 2, 3, 4 \dots$

If the projects are successful, the firm can repay the loans; and it does repay them. An unsuccessful project means that the firm has taken a risk because good projects are risk-free. If a project is unsuccessful, lenders deny future loans: the *ostracism punishment*. Due to the ostracism, the firm must interrupt production forever, because the firm cannot self-finance projects. This model has a *reputational equilibrium:* The borrower retains a reputation for choosing good projects by doing so. If the firm changes to bad projects and lenders learn about it, they will deny future loans; and the firm must stop business.

The key findings of the paper are in Sections 2–4: The incentive to invest in bad projects is highest in the synchronous environment, lowest in the asynchronous environment when the firm has an existing good project, and at the intermediate level in period 1 of the asynchronous environment when the firm has no existing projects. Therefore, it is possible that lending is profitable only in the asynchronous environment.

In Section 5, we extend the findings of Sections 2–4 to other information conditions. In Sections 2–4, the borrower can hide risk-shifting until the risk has been realized. In Section 5, the borrower can hide risk-shifting for a period. We can replicate the above-mentioned key findings of Sections 2–4 in Section 5.

The banking theory proposes many useful tools to alleviate information problems in the borrower-lender relationship: for example, monitoring and screening (Chiesa, 2001, 2008; Daley et al., 2020; Diamond, 1984; Krasa & Villamil, 1992; Lester et al., 2019), relationship lending (Chemmanur & Fulghieri, 1994; Elyasiani & Goldberg, 2004; Hauswald & Marquez, 2006; Song & Thakor, 2007), loan covenants (Cheng & Milbradt, 2012; Gârleanu & Zwiebel, 2009), credit history (Ordoñez et al., 2019; Pagano & Jappelli, 1993), capital structure (DeMarzo & Sannikov, 2006; François & Morellec, 2004; Herranz et al., 2015, 2017), and collateral (Araujo et al., 2005; Inderst & Mueller, 2007; Niinimäki, 2009). Our contribution to this rich literature is to show that the parameter set of reputational equilibria is slightly larger when projects are asynchronous rather than synchronous.

This paper is also related to the literature on reputational formation, contract enforcement, and ostracism punishments. Klein and Leffler (1981) provide a classic paper on reputational formation in product markets. The theory on finance has extended their analysis; for example, Allen (1983), Eaton and Gersovitz (1981), Herranz et al., (2015, 2017), Kehoe and Levine (1993), and Sachs (1984). From this research, we borrow the idea of the ostracism punishment: if a firm changes to bad projects and lenders learn about it, they will deny future loans.

This paper is most related to Herranz et al. (2015). They develop a dynamic model in which risk-averse entrepreneurs manage risk by selecting the size, capital structure, and default of their firms and their own consumption. If the firm's assets are insufficient to repay the debt, the entrepreneur can use private assets to cover the difference. If the entrepreneur chooses a default, they are excluded from the credit market and cannot operate the firm for many periods. Their paper shows that more risk-averse entrepreneurs run smaller, more highly leveraged firms and default less, because running a smaller firm with higher debt reduces personal funds at risk with the firm. The ostracism punishment—the exclusion from credit markets—and limited liability play crucial roles in Herranz et al. (2015) and in our model. However, the incentive effects of the asynchronous environment have no role in their theory. We abstract away from optimal scale, capital structure, risk aversion, and debt renegotiation and the owner's chance to save their firm from bankruptcy by injecting fresh capital into it. These features are important in Herranz et al. (2015). Their analysis is extended in Herranz et al. (2017).

The paper is structured as follows: In Sections 2–4, we examine risk-shifting when the borrower can hide risk-shifting until the risk realizes. In Section 5, we investigate risk-shifting when the borrower can hide it for a period. Section 6 provides our conclusions.

2. Synchronous environment

Consider a risk-neutral economy with wealth-constrained firms (borrowers), short-lived lenders, and an infinite number of periods. We label them period 1, period 2, period 3, and so on. Firms and lenders maximize their lifetime profits. Each firm can run at most two projects (i.e., production technologies) in each period. A project lasts for two periods, which we refer to as the first and second periods.[1] Projects have two possible types: good (G) and bad (B). The borrower chooses the type, and this choice cannot be immediately verified by others. Each investment type requires one unit of initial investment. The state of the aggregate economy is either an upturn or a downturn. It is an upturn with probability p and a downturn with probability $1-p$, and these states are independent across time and are not affected by the borrower's decisions. A good project pays Y_G in its first payoff period and $1+Y_G$ in its second and last payoff period. These payoffs do not depend on the state of the aggregate economy, which makes the good project riskless. For bad projects, the return in the first payoff period is Y_B if the current macro state in that period is an upturn, and zero otherwise, $Y_B > Y_G$. The bad investment return in the second payoff period is $1+Y_B$ if the macro state is an upturn in both the first and second return periods, and the return is zero otherwise.[2] That is, a bad investment becomes permanently worthless if the macro state is a downturn in the first return period. When a downturn occurs, all bad projects become worthless whether they are in their first or second return period. Therefore, a bad project produces Y_B with probability p at the end of the first period, and $1+Y_B$ with probability p^2 at the end of the second period. We make the following assumption:

Assumption 1. The NPV of good projects is positive, and the NPV of bad projects is negative:

$$Y_G + \delta(1+Y_G) > 1+r > pY_B + \delta p^2(1+Y_B). \tag{2.1}$$

Here $1+r$ is the risk-free gross interest of the economy, and $\delta = 1/1+r$ is the discount factor. In addition, $L, L<1$, is the liquidation value of a successful project (good or bad) after the first period.

2.1. Probability of success

Again, good projects are always successful. If a firm runs one bad project, it succeeds with probability p. If the firm simultaneously starts two bad projects, both projects are successful with probability p and unsuccessful with probability $1-p$. In this section, a borrower starts two new projects in every second period: period 1, period 3….

2.2. Information flows

In Sections 2–4, the chosen project type is the borrower's private information if the project is successful.[3] Borrowers cannot hide unsuccessful projects. Everyone observes if a project is unsuccessful, and each new generation of lenders knows whether a firm has previously had unsuccessful projects. In Sections 2–4, the lender cannot acquire more information. In Section 5, monitoring discloses the project output (Y_B or Y_G) at the end of the period as in Diamond (1984) and Krasa and Villamil (1992).

Assumption 2. *The firm's owners consume the profit of the firm at the end of each period.*

Assumption 2 means that the firm cannot use retained earnings to pay for investments.

Since borrowers have no initial wealth and consume the realized output at once, the projects are fully debt-financed in every period in each model of this paper. Since lenders live only for a period, firms face a new set of lenders in every period. Each lender is endowed with two units of capital that can either be stored at a gross return $1+r$ or lent for a period. The number of lenders is large compared to the number of potential projects. Therefore, lenders compete for borrowers and are ready to grant loans if the expected repayment is at least $1+r$ (the *lenders' participation constraint*).

Consider loan repayment $1+r$ and assume that the borrower invests in good projects. How can a borrower repay the short-term

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[1] Note that "the first period" is the first period of the project and "period 1″ is the first period of the economy.

[2] For computational convenience, we assume that the difference between the outputs—the output of the first period and the output of the second period—is one. That is, a good (bad) project produces $1+Y_G$ $(1+Y_B)$ in the second period and Y_G (Y_B) in the first period, $1+Y_G-Y_G=1$, $1+Y_B-Y_B=1$. The assumption is not critical. The appendix presents numerous project outputs which do not change the key findings of the paper.

[3] Lenders cannot observe the output of a successful project: Y_B or Y_G. This is a common assumption in multiperiod risk-shifting models, for example, Diamond (1989, 1991). If lenders observe Y_B and Y_G, they can identify risk-shifting at the end of the period and the firm can gamble only for a period. This scenario arises in Section 5.

loan $1+r$ after the first project period? It is possible that the interim output, Y_G, does not cover the repayment $1+r$. The firm acts as follows: At the start of the first project period, Lender 1 contacts the firm and lends a unit for a period (principal 1). The firm invests it in a good project for two periods. At the end of the first period, the project produces interim output Y_G, and a new lender (lender 2) arrives and lends a unit to the firm (principal 2). The firm allocates principal 2 to repay the maturing loan, one unit (principal 1), to lender 1. In addition, the firm uses the interim output Y_G to pay interest r on the maturing loan ($Y_G > r$). Lender 1 receives $1+r$ in total.

Since good projects are profitable, the firm does not disregard investment opportunities. The firm will start a project if lenders finance it. If a project is successful, the firm repays the loan. We ignore enforcement problems in which a borrower does not repay a loan even if they have sufficient wealth for the repayment.

2.3. The fully efficient equilibrium

The borrower's project choice—the borrower chooses a good project—is observable. Since lenders do not finance bad projects, the borrower invests in good projects. In the current model, however, the efficient equilibrium is unachievable because we assume that the chosen project type is unobservable.

2.4. Permanent ostracism

We make the following assumption.

Assumption 3. *There is always permanent ostracism for the borrower no matter what the borrower does if the borrower has at least one bad project and lenders learn about it.*

The idea behind this assumption is the same as in the classic paper on reputational formation and contract enforcement in product markets, Klein and Leffler (1981, p. 617): "Therefore, if a firm cheats and supplies to any individual a quality of product less than contracted for, all consumers in the market learn this and all future sales are lost". This assumption is standard in the literature on product quality and is also used in the theory of finance.

Again, the realization of an economic downturn causes the failures of bad projects. These failures reflect risk-shifting to lenders—because good projects are risk-free—and lead to punishment in which lenders ostracize the firm from future borrowing. The firm must liquidate existing projects and interrupt production forever because it cannot self-finance projects. The firm suffers the same punishment—permanent ostracism—even if it has both a good project and a bad project.

2.5. The equilibrium

We have only one equilibrium: The reputational equilibrium. The borrower's project choice is unobservable. Therefore, the standard risk-shifting problem is present: A firm is tempted to invest in bad projects. In the reputational equilibrium:

- A borrower knows that there is always permanent ostracism for them if they have at least one bad project and lenders learn about it.
- Lenders know the borrower's expected profit from the choice of good projects and from the bad projects under the ostracism punishment. Lenders must believe that the borrower will invest in good projects even if the choice is unobservable. That is, the *borrower's incentive constraint* must be met: Lenders are ready to finance a project only if the profit-maximizing choice of the firm is to invest in good projects. Then, a lender is ready to grant a loan for a period at interest $1+r$. If the incentive constraint is not met, lenders deny loans.
- If the incentive constraint is met, lenders finance the borrower's project(s) in period 1 and continue to do so if and only if the borrower has not been caught participating in bad projects.

A firm gets an opportunity to produce in period 1 if its incentive constraint is met. The firm retains a reputation for choosing good projects by doing so. If the firm changes to bad projects and the lenders learn about it, they will deny future loans.

2.6. Definition of reputational equilibrium

If the incentive constraint is not met, the firm cannot attract loans and start projects. If the incentive constraint is met, the firm offers loan interest $1+r$ in each period and invests in good projects in each period. Lenders grant loans in period 1 and continue to do so in future periods if and only if the firm has not been caught participating in bad projects.

Infinitely repeated moral hazard games have an infinite number of equilibria. The simplest equilibrium of the present game is a pessimistic equilibrium: lenders expect that the firm will invest in bad projects, and they deny loans. The firm cannot start projects. We focus on the reputational equilibria in which the chosen projects are good, and the total surplus is the highest. To be precise, we examine the equilibrium which is most profitable for borrowers. This is consistent with the idea that the supply of investment capital is abundant.

2.7. Dynamic programming

The dynamic programming structure in the synchronous environment is as follows: let $z = 1$ refer to the economy in the economic upturn and $z = 0$ in the downturn. A firm invests in two new projects in odd-numbered periods and does not invest in even-numbered periods. Let x_1 be the type of the first project and let x_2 be the type for the second project. Here, $x_i, i \in \{1,2\}$, can be either G (the chosen project is good) or B (a bad project). Let $U(x_1, x_2, z)$ be the payoff of the borrower's holdings (x_1, x_2), where U comprises the current and possible future payments. Further, $v(x_1, x_2)$ is the expected value of $U(x_1, x_2, z)$ prior to the realization of z. The borrower makes the following payoffs:

If the borrower chooses two good projects, the expected payoff is:

$$v(G,G) = pU(G,G,1) + (1-p)U(G,G,0) = \tag{2.2}$$

$$2(1+\delta)(Y_G - r) \ + \ \delta^2 \ max[v(G,G), v(B,B)].$$

Further, $U(G,G,1) = U(G,G,0)$ because a good project is risk-free. The borrower chooses two good projects in period t for the next two periods. After these periods, they can again choose two projects: good or bad.

Since limited liability may make the choice of the bad projects profitable, a borrower will maximize their profit from limited liability by choosing two bad projects at the same time. If the borrower does not take advantage of limited liability, they will choose two good projects. The borrower will never choose both project types—a good project and a bad project—at the same time. In this mixed allocation, the limited liability advantage is low (if any) and the risk-shifting becomes public with the same probability as if the firm had two bad projects.

If the borrower chooses two bad projects, the expected payoff is:

$$v(B,B) = pU(B,B,1) + (1-p)U(B,B,0) = \tag{2.3}$$

$$2p(1+p\delta)(Y_B - r) \ + \ (p\delta)^2 \ \max[v(G,G), v(B,B)].$$

The borrower chooses two bad projects in period t for the next two periods. After these periods, they can again choose two projects: good or bad.

The choice situation is identical in each period: 1,3,5…This consistency means that the optimal choice is identical in these periods. The firm chooses two good projects in each odd-numbered period or two bad projects in each odd-numbered period. If the LHS of (2.2) exceeds the LHS of (2.3)—that is, $v(G,G) \geq v(B,B)$—Eq. (2.2) denotes the NPV of the firm's expected lifetime profit in the current period. This optimal choice means that $\max[v(G,G), v(B,B)] = v(G,G)$ in (2.2), and we can express (2.2) as:

$$v(G,G) = 2(1+\delta)(Y_G - r) \ + \ \delta^2 \ v(G,G), \tag{2.4}$$

or $(1-\delta^2)v(G,G) = 2(1+\delta)(Y_G - r)$, or

$$v(G,G) = \frac{2(Y_G - r)}{1-\delta}. \tag{2.5}$$

Alternatively, if the LHS of (2.3) exceeds the LHS of (2.2)— $v(B,B) > v(G,G)$—Eq. (2.3) indicates the NPV of the expected lifetime profit. This NPV means that $\max[v(G,G), v(B,B)] \ = \ v(B,B)$ in (2.3), and we can write (2.3) as:

$$\left[1 - (p\delta)^2\right] \ v(B,B) = 2p(1+p\delta)(Y_B - r), \tag{2.6}$$

or

$$v(B,B) = \frac{2p(Y_B - r)}{1-\delta p}. \tag{2.7}$$

For clarity, we detail the lifetime profit functions.

2.8. Good projects

If $\boldsymbol{v(G,G) \geq v(B,B)}$, then the firm chooses two good projects in odd-numbered periods and makes a lifetime profit of:

$$[2(Y_G - r) + \delta 2(Y_G - r)] + \delta^2[2(Y_G - r) + \delta 2(Y_G - r)] + \delta^4[\ldots] + \tag{2.8}$$

Again, r is the fixed interest rate, and δ is the discount factor. In each set of square brackets, we observe the firm's profit from two synchronous good projects. Consider the term in the first set. Here $2(Y_G - r)$ shows the profit in the first project period, and $\delta 2(Y_G - r)$ is the profit in the second project period. In detail, in the first period, two projects produce interim output $2Y_G$, and the firm pays interest $2r$ and makes a profit of $2(Y_G - r)$. The firm's owner consumes it. At the end of the first period (= at the start of the second period), the value of the firm's assets is two and consists of the two existing good projects. This value is equal to the principals of the two short-term loans. These loans replace the short-term loans of the first period.

In the second project period, two projects produce $2(1 + Y_G)$, the firm pays the interest and principal $2(1 + r)$ and makes a profit of $2(1 + Y_G) - 2(1 + r)$ or $2(Y_G - r)$. The owner consumes it. After the second period, the values of the assets and loans are zero.

Consequently, two good projects yield $2(Y_G - r)$ in both periods. Thereafter, the firm starts two new, good projects in odd-numbered periods. These projects yield $2(Y_G - r)$ in both periods (We have the same terms in each set of square brackets). The owner can consume

$2(Y_G - r)$ in each period. The NPV of the lifetime profit (= consumption) is:

$$\pi_G = \frac{2(Y_G - r)}{1 - \delta}. \tag{2.9}$$

Here Y_G, r, and δ are fixed. Therefore, π_G is fixed. In each period $t = 1, 2, 3\ldots$, the NPV of the future profit is π_G. In the rest of the paper, π_G is fixed and refers to the NPV of the lifetime profit from good projects in the synchronous environment.

2.9. Bad projects

If $\boldsymbol{v}(\boldsymbol{B}, \boldsymbol{B}) > \boldsymbol{v}(\boldsymbol{G}, \boldsymbol{G})$, a firm starts two bad projects in odd-numbered periods and makes an expected lifetime profit of:

$$\{ \quad \max[0, 2p(Y_B - r)] + \delta p \max[0, 2p(Y_B - r)]\} + \tag{2.10}$$

$$+p^2\delta^2 \quad \{ \quad \max[0, 2p(Y_B - r)] \; + \; \delta p \max[0, 2p(Y_B - r)]\} \; + \; p^4\delta^4\{\ldots\}$$

The firm invests in bad projects until a downturn hits the economy, the projects fail, and the choice of the bad projects is apparent. The upper row shows the expected profit from the first two synchronous bad projects. In the first project period, both projects are successful with probability p. Then, two bad projects produce $2Y_B$, and the firm pays interest $2r$ and makes a profit of $2(Y_B - r)$. The owner consumes it. With probability $1 - p$, a downturn hits the economy, both projects are valueless, and the firm cannot repay the loans and fails. The expected profit is $2p(Y_B - r)$ for the first period.

The firm can continue in the second project period if the projects do not fail during the first period (with probability p). We focus on this scenario. Consider the second term in the upper row of (2.10). For the second period, the existing bad projects are successful with probability p. Then, these projects produce $2(1 + Y_B)$, and the firm repays the interest and principal $2(1 + r)$ and makes a profit $2(Y_B - r)$. The owner consumes it. With probability $1 - p$, a downturn hits the economy during the second period, both projects become valueless, and the firm cannot repay the loans and fails. The expected profit is $2p(Y_B - r)$ in the second period if the bad projects are successful during the first project period.

In sum, two bad projects yield an expected profit of $2p(Y_B - r)$ in both periods. If the firm chooses bad projects repeatedly, its owners earn $2p(Y_B - r)$ in each period until the risk is realized and the firm fails (We have the same terms in each curly brackets). The NPV of the expected lifetime profit is:

$$\pi_B = \frac{2p(Y_B - r)}{1 - \delta p}. \tag{2.11}$$

In each period, $t = 1, 2, 3\ldots$, the NPV of the expected lifetime profit is fixed: π_B. In the rest of the paper, π_B is fixed and denotes the expected lifetime profit from two bad projects in the synchronous environment.

As to the optimization objective of the firm, it maximizes its expected lifetime profit by choosing either good projects or bad projects: π_G or π_B. The firm cannot choose anything else; it can choose only the project type. Even if lenders cannot observe the firm's choice, they anticipate the choice correctly and make loans only if the firm prefers good projects: $\pi_G \geq \pi_B$. In the rest of the paper, we focus on the more interesting scenario.

Assumption 4. In a synchronous environment, a firm prefers bad projects: $\pi_B > \pi_G$.

Rational lenders foresee this preference and deny loans. We give a numeric example.

Example 1. *Consider an economy:* $Y_G = 0.0505, Y_B = 0.09, r = 0.05, p = 0.25$. *The NPV of a good (bad) project is positive (negative), that is, Eq. (2.1) is met,* $Y_G + \delta(1 + Y_G) > 1 + r > pY_B + \delta p^2(1 + Y_B)$, *because,* $1.051 > 1.05 > 0.0874$. *Assumption 4 is met,* $\pi_B > \pi_G$, *because* $\pi_B = 0.026$ *and* $\pi_G = 0.021$. .

We can measure the magnitude of the incentive problem using *the incentive compatible output premium for bad projects* in the synchronous environment: Δ_{sync} . If we insert $Y_B = Y_G + \Delta_{sync}$ into π_B; then we find from $\pi_G = \pi_B$ that the incentive compatible output premium is:

$$\Delta_{sync} = \frac{(1 - p)(Y_G - r)}{p(1 - \delta)} \tag{2.12}$$

If the real size of the output premium Δ is smaller (larger) than Δ_{sync}, then the firm prefers good (bad) projects. In the economy of Example 1, for instance, we have $\Delta_{sync} = 0.0315$. This value means the critical value of Y_B is 0.082, because $Y_B = Y_G + \Delta_{sync} = 0.0505 + 0.0315 = 0.082$. If $Y_B > 0.082$ ($Y_B < 0.082$), then the lifetime profit from bad projects exceeds (is lower than) the lifetime profit from good projects; and the firm will invest in bad (good) projects.

Given Assumption 4, the real size of the output premium Δ exceeds Δ_{sync}. A borrower favors bad projects. Rational lenders know this preference and deny loans. In the rest of the paper, we measure the magnitude of the incentive problem in alternative environments by finding out the incentive compatible output premium for bad projects in each environment and by comparing this premium with Δ_{sync}. We need the following result below:

Lemma 1. $p(Y_B - r) > Y_G - r$.

Proof. The existence of the risk-shifting problem, $\pi_B > \pi_G$, means $p(Y_B - r) > Y_G - r$. *QED*.

3. Asynchronous environment: later periods

In this section, we show that firms may avoid risk-shifting in the asynchronous environment even if risk-shifting prevents lending in the synchronous environment. To begin, we characterize the asynchronous environment.

In Fig. 2, a firm starts the first project at the beginning of period 1 and the second one at the beginning of period 2. Thereafter, one project expires in each period while the firm replaces it with a new one. The firm has one project in period 1 and two projects in the following periods. Consider period 1. The firm runs project A1 in periods 1 and 2. It expires at the end of period 2. The firm introduces project A2 at the beginning of period 3 and runs it during periods 3 and 4. Consider project B1. The firm starts it at the beginning of period 2 and runs it in periods 2 and 3. In the beginning of period 3, project A1 is an *old project* and expires, Project B1 is an *existing project*, and project A2 is a *new project*.

In period 1, the firm has one loan unit, because its size is one. The loan repayment is $1 + r$ at the end of period 1. In periods $t \geq 2$, the firm has two loan units, because its size is two. At the end of each period, the firm repays $2(1 + r)$. The loans are short-term loans. Given the repayment policy of the firm, the firm replaces maturing short-term loans with new short-term loans at the end of each period (specifically, it replaces the principals of the maturing loans with the principals of the new loans) and allocates the realized output to pay interest on the maturing loans. The true cost of the loans is r in period 1 and $2r$ in later periods.

Consider good projects. A firm makes a profit $Y_G - r$ in period 1 and $2(Y_G - r)$ in later periods. In period 1, the NPV of the lifetime profit is $Y_G - r + \delta\pi_G$ (fixed). In periods 2,3, 4 …, the NPV of the lifetime profit is π_G (fixed). Good projects yield the same lifetime profit π_G in periods $t = 2, 3, 4\ldots$ in the synchronous and asynchronous environments.

Consider bad projects. A firm makes the expected profit $p(Y_B - r)$ in period 1 and $2p(Y_B - r)$ in later periods. In period 1, the NPV of the lifetime profit is $p(Y_B - r) + \delta p\pi_B$ (fixed). In periods 2,3, 4…, the NPV of the lifetime profit is π_B (fixed). Bad projects yield the same expected lifetime profit π_B in periods $t = 2, 3, 4\ldots$ in both environments.

We explore whether the firm chooses good or bad projects. First, in subsection 3.1, we study periods $t = 2, 3, 4\ldots$ when the firm has an existing project. Thereafter, in Section 4, we examine risk-shifting in period 1 when the firm lacks an existing project.

3.1. Period t, $t \geq 2$

This subsection provides the following result: If the existing project of the firm is good, then the expected profit from the choice of a bad new project in the following periods is lower than when introducing synchronous projects.

Again, the firm's optimization objective is to maximize the lifetime profit. To do this, the firm chooses good or bad projects. The existing project is good or bad. In the asynchronous environment, the dynamic programming structure of the model is as follows: again, $z = 1$ refers to the economic upturn, and $z = 0$ is a downturn. Let x_1 be the type of project in its first period (= a new project), and let x_2 be the type of project in its second period (= an existing project). Here, x_i, $i \in \{1, 2\}$, can be either good or bad. Let $U(x_1; x_2, z)$ be the payoff to the borrower who holds (x_1, x_2), where U comprises the current and possible future payments. Further, $V(x_1, x_2)$ is the expected value of $U(x_1; x_2, z)$ prior to the realization of z. Dynamic programming generates the following profit functions.

Case 1. The existing project is good, and the firm chooses a good new project:

$$V(G;G) = pU(G;G,1) + (1-p)U(G;G,0) = 2(Y_G - r) + \delta\max[V(G;G), V(B;G)]. \tag{3.1}$$

Case 2. The existing project is bad, and the firm chooses a good new project:

$$V(G;B) = pU(G;B,1) + (1-p)U(G;B,0) = \tag{3.2}$$

$$p(Y_G + Y_B - 2r) \; + \; p\delta\max[V(G;G), V(B;G)] + (1-p)\max[0, Y_G + L - 2(1+r)].$$

With probability p, both projects are successful. In the following period, the firm can choose either a good project or a bad project when the existing project is good [$V(G;G)$ or $V(B;G)$].With probability $1 - p$, the bad project is unsuccessful (valueless) in the current period and this information surfaces. Lenders deny new loans and require repayments $2(1 + r)$. The existing good project produces $Y_G + L$, where $L, L < 1$, labels the liquidation value of the good project after the first period. Moreover, the proceeds of the firm may be

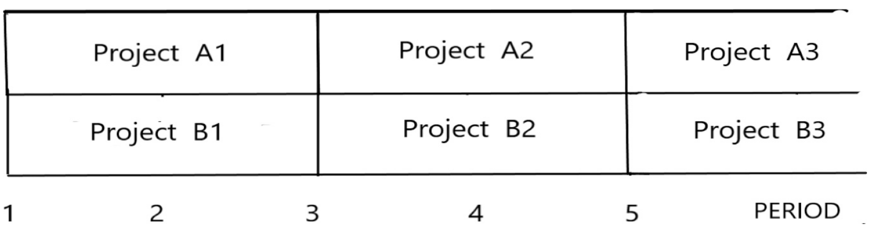

Fig. 1. In a synchronous environment, a firm starts two projects in odd-numbered periods.

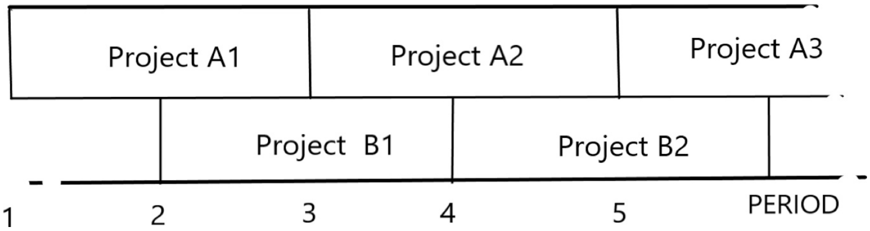

Fig. 2. The asynchronous environment: A borrower starts a new project in each period.

positive even if the bad project is unsuccessful. Alternatively, the proceeds are zero owing to limited liability.

Case 3. The existing project is good, and the firm chooses a bad new project:

$$V(B;G) = pU(B;G,1) + (1-p)U(B;G,0) = \tag{3.3}$$

$$p(Y_B + Y_G - 2r) + p\delta\, \max[V(G;B), V(B;B)] + (1-p)\max[0, Y_G + 1 - 2(1+r)].$$

With probability p, both projects are successful. In the following period, the firm can choose either a good project or a bad project when the existing project is bad [$V(G;B)$ or $V(B;B)$]. With probability $1-p$, the bad project is unsuccessful in the current period and this information surfaces. Lenders deny new loans and require repayments $2(1+r)$. The old, good project expires, producing $1 + Y_G$. Again, the proceeds of the firm may be positive even if the bad project is unsuccessful. Alternatively, the proceeds are zero.

Case 4. The existing project is bad, and the firm chooses a bad new project:

$$V(B;B) = pU(B;B,1) + (1-p)U(B;B,0) = \tag{3.4}$$

$$2p(Y_B - r) + p\delta\, \max[V(G;B), V(B;B)].$$

With probability p, both projects are successful. In the following period, the firm can choose either a good project or a bad project when the existing project is bad. With probability $1-p$, both bad projects are unsuccessful in the current period, the borrower's worth is zero, and the borrower must stop business.

Lemma 2. *A mixed combination—a combination of a good project and a bad project—yields a lower expected profit in each period and in each number of periods than a combination of two bad projects.*

Proof. If a new project is good (bad) in a mixed combination, the existing project is bad (good). Under both combinations, the choice of a bad project surfaces and the firm must stop business with probability $1-p$. In the current period, a mixed combination yields the expected profit of:

$$\Omega_1 = p(Y_G + Y_B - 2r) + (1-p)\, \max[0, Y_G + L - 2(1+r)], \tag{3.5}$$

or

$$\Omega_2 = p(Y_G + Y_B - 2r) + (1-p)\, \max[0, Y_G + 1 - 2(1+r)]. \tag{3.6}$$

In Ω_1 (Ω_2), the new project is good (bad) and the existing project is bad (good). Since $L < 1$ (here L refers to the liquidation value of an existing good project), then we know $\Omega_1 \leq \Omega_2$. It is enough to show that Ω_2 is less profitable than the combination of two bad projects in a period: $\Omega_2 < 2p(Y_B - r)$. If the term in the square brackets in (3.6) is zero, $\Omega_2 < 2p(Y_B - r)$ is true:

$$p(Y_G + Y_B - 2r) < 2p(Y_B - r). \tag{3.7}$$

If the term in the square brackets in (3.6) exceeds zero, we can rewrite $\Omega_2 < 2p(Y_B - r)$ as:

$$p(Y_B - r) + Y_G - r - (1-p)(1+r) < 2p(Y_B - r). \tag{3.8}$$

This inequality occurs, because $p(Y_B - r) > Y_G - r$ (Lemma 1). If we compare a mixed combination with a combination of two bad projects, we know three facts. First, given (3.7) and (3.8), a mixed combination yields a lower expected profit in a period than the combination of two bad projects. Second, the choice of the bad project surfaces with the same probability $1-p$ under both combinations. The third fact, given the second, is that a firm must stop business under both combinations with probability $1-p$ after each period. Given these three facts, a mixed combination is less profitable in each period and in any number of periods. *QED*.

Lemma 3. *A firm whose existing project is bad will not choose a good new project.*

Proof. This firm can choose a combination of two bad projects. Given Lemma 2, any positive number of periods with mixed projects (good and bad) is less profitable than the same number of periods with two bad projects. Owing to Assumption 4, $\pi_B > \pi_G$, any number of periods with two good projects is less profitable than the choice of two bad projects. *QED*

Lemma 4. *We can eliminate $V(G;B)$ and Case 2.*

Proof. Lemma 3. *QED.*

Now we can list the cases as follows:

$$\textit{Case } 1. V(G;G) = 2(Y_G - r) + \delta \max[V(G;G), V(B;G)]. \tag{3.9}$$

$$\textit{Case } 3. V(B;G) = p(Y_B + Y_G - 2r) + (1-p)\max[0, Y_G + 1 - 2(1+r)] + p\delta V(B;B).$$

$$\textit{Case } 4. V(B;B) = 2p(Y_B - r) + p\delta V(B;B).$$

We can simplify them to:

Lemma 5. *In Case 1, choice* $\max[V(G;G), V(B;G)] = V(B;G)$ *is impossible.*

Proof. If $\max[V(G;G), V(B;G)] = V(B;G)$, Case 1 provides the expected payoff $V(G;G) = 2(Y_G - r) + \delta V(B;G)$. However, by choosing a bad project already in the current period, the firm makes expected payoff $V(B;G)$. This payoff exceeds $V(G;G) = 2(Y_G - r) + \delta V(B;G)$ when $\max[V(G;G), V(B;G)] = V(B;G)$. *QED.*

That is, if risk-shifting is profitable after a period, it is even more profitable in the current period owing to discounting. Given Lemma 5, we have $\max[V(G;G), V(B;G)] = V(G;G)$ in Case 1, and Case 1 can be rewritten as $V(G;G) = 2(Y_G - r) + \delta V(G;G)$ and indicates that $V(G;G) = 2(Y_G - r)/(1 - \delta)$. Here the RHS is π_G.

In Case 4, we can distinguish $V(B;B)$ from $V(B;B) = 2p(Y_B - r) + p\delta V(B;B)$ as $V(B;B) = 2p(Y_B - r)/(1 - \delta p)$. The RHS is π_B. We insert it into Cases 3 and 4. In Case 3, we abbreviate the profit of the current period using Ω_2, and express the cases in the final forms:

$$\textit{Case } 1. V(G;G) : \pi_G. \tag{3.10}$$

$$\textit{Case } 3. V(B;G) : \Omega_2 - 2p(Y_B - r) + \pi_B.$$

$$\textit{Case } 4. V(B;B) : \pi_B.$$

We can describe these cases as follows:

Case 4. The existing project is bad, and the firm chooses a new bad project in each period until the risk realizes. The projects yield the expected total profit $2p(Y_B - r)$ in each period and thus the lifetime profit adds up to $\pi_B = 2p(Y_B - r)/(1 - p\delta)$. This fixed profit is the same as the fixed lifetime profit from bad projects in the synchronous environment.

If the existing project is good, then the firm has two alternatives. Either it chooses good projects forever (Case 1) or gradually transforms its good project assortment into a bad project assortment during the next two periods (Case 3).

Case 1. The existing project is good, and the firm chooses a good new project in each period. The projects yield $2(Y_G - r)$ in each period, and the NPV of the lifetime profit amounts to $\pi_G = 2(Y_G - r)/(1 - \delta)$. This fixed profit is the same as the lifetime profit from good projects in the synchronous environment.

Case 3. In the current period t, the existing project is good. The firm chooses a bad new project. In period t, the firm has both a good project and a bad project (Bad project 1 in Fig. 3). Its existing project (introduced in period $t - 1$) is good, and the new project (initiated in period t) is bad.

The existing good project expires at the end of period t, and the firm replaces it with a new bad project (Bad project 2 in Fig. 3) at the beginning of period $t + 1$. Thereafter, in periods $t+1, t+2\ldots$, the firm has only bad projects. The firm transforms its good project assortment into a bad project assortment during two periods. The transformation may be profitable even if the expected profit in period t (the firm has both a good project and a bad project) is lower than the profit in each of the previous periods (the firm has two good projects).

We focus on Cases 1 and 3 in which the existing project is good. Does the firm continue with good projects (Case 1) or does it transform its good project assortment into a bad assortment (Case 3)? The firm continues with good projects—Case 1 is more profitable than Case 3—if $\pi_G \geq \Omega_2 - 2p(Y_B - r) + \pi_B$. We get the following result:

Proposition 1.. *When the existing project is good in period 2 (or in period $t, t \geq 2$) in the asynchronous environment, it is possible that the firm continues with good projects even if the firm chooses bad projects in the synchronous environment, $\pi_G < \pi_B$.*

Proof. This result arises if $\pi_G \geq \Omega_2 - 2p(Y_B - r) + \pi_B$ even if $\pi_G < \pi_B$. The result is possible, because $\Omega_2 < 2p(Y_B - r)$ (see (3.7) and (3.8) in Lemma 2). *QED.*

Why do the profits from risk-shifting differ in these two environments? The difference is based on the difference in outputs during period t (the first risk-shifting period). There are no differences during later periods. In both environments, the firm has only bad projects in periods $t + 1, t + 2\ldots$, and these projects yield the same expected lifetime profit in both environments: π_B. In both environments, the choice of the bad projects surfaces with the same probability $1 - p$. In both environments, good projects yield the same lifetime profit after period t: π_G. Therefore, the expected long-term loss of getting caught for risk-shifting—which is ostracism from future borrowing—is the same in both environments.

In the first risk-shifting period t, $t \geq 2$, the firm has a good project and a bad project in the asynchronous environment. In the

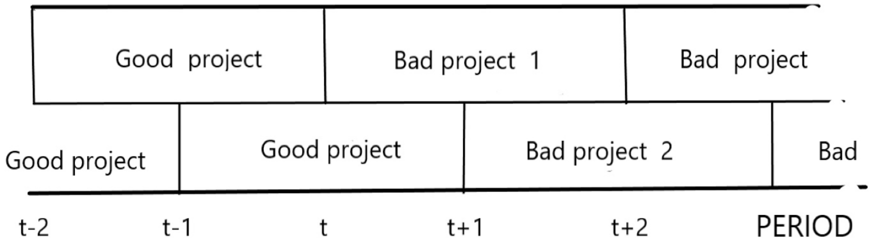

Fig. 3. *Case 3.*

synchronous environment, the firm has two bad projects. Therefore, in the asynchronous environment the short-term gain from risk-shifting is half as high as in the synchronous environment even if the long-term loss—which is ostracism from future borrowing—is the same in both environments.

Consider successful bad projects in the first risk-shifting period t, $t \geq 2$. Bad projects are successful with probability p in both environments. In the synchronous environment, the firm can simultaneously reallocate 100 per cent of its assets (Fig. 1). This reallocation makes it profitable to replace good projects with bad ones. After the change, the firm has 100 per cent of its assets in two bad projects whose net output is very valuable: $2Y_B$.[4] In the asynchronous environment, the firm can reallocate 50 per cent of its assets simultaneously. This reallocation makes it unprofitable to replace good projects with bad ones. If the firm chooses a new bad project, the firm has only 50 per cent of its assets in bad projects—whose net output is more valuable than the net output of good projects, $Y_B > Y_G$, during period t (Fig. 3). The rest of the firm's assets are tied up in the existing good project whose net output Y_G is low, $Y_G < Y_B$. The total value of the net output is $Y_G + Y_B$. The total value of the net output is higher in the synchronous environment than in the asynchronous environment, $2Y_B > Y_G + Y_B$, in period t.

Alternatively, we can examine risk-shifting using incentive compatible premiums. Again, Δ_{sync} is the highest incentive compatible output premium for the bad project in the synchronous environment, $Y_B = Y_G + \Delta_{sync}$, such that the firm is indifferent between good and bad projects in this environment: $\pi_G = \pi_B$. Next we find the incentive compatible output premium in the asynchronous environment Δ_{async}, $Y_B = Y_G + \Delta_{async}$, such that the firm is indifferent between good and bad new projects if the existing project is good.

Proposition 2. *In the asynchronous environment, the incentive compatible output premium for the bad project, Δ_{async}, is:*

$$\Delta_{async} = \frac{2}{1+p\delta} \quad \Delta_{sync} - \frac{(1-p\delta)(1-p)}{(1+p\delta)p} \quad \max[0, Y_G + 1 - 2(1+r)], \tag{3.11}$$

which means $\Delta_{async} > \Delta_{sync}$.

Proof. The firm favors good projects if $\pi_G \geq \Omega_2 - 2p(Y_B - r) + \pi_B$ or

$$\frac{2(Y_G - r)}{1-\delta} \geq -p(Y_B - Y_G) + (1-p)\max[0, Y_G + 1 - 2(1+r)] + \frac{2p(Y_B - r)}{1-\delta p}.$$

Inserting $Y_B = Y_G + \Delta_{async}$ into this gives (3.11). If the term in the square brackets in (3.11) is zero, we have $\Delta_{\text{async}} > \Delta_{\text{sync}}$ because $2/(1+\text{p}\delta) > 1$. If the term in the square brackets in (3.11) is positive, then (3.11) can be rewritten as:

$$\Delta_{async} = [1 + \frac{\delta(1-\delta p)}{(1+p\delta)}]\Delta_{sync} + \frac{(1-p\delta)(1-p)(1+r)}{(1+p\delta)p} \quad , \tag{3.12}$$

which exceeds Δ_{sync} since the term in the square brackets in (3.12) exceeds one and the latter term is positive. *QED.*

The incentive problem is slighter in the asynchronous environment. To ensure this level is the case, we focus on this scenario and investigate it thoroughly. Thus, we make the following assumption in the rest of the section and in Section 4.

Assumption 5. $0 < \Delta \leq \Delta_{async}$,

Here Δ is the real size of the output premium: $Y_B = Y_G + \Delta$. Under Assumption 5, the firm chooses a good new project if the existing project is good. Assumption 5 generates a stronger result.

Proposition 3. *A firm whose existing project is good continues with good projects forever.*

Proof. Consider period 2 when the existing project is good. Given Assumption 5, the incentive constraint is satisfied, and the firm chooses a good new project in period 2. Owing to this choice, the existing project is good in period 3. As a result, the firm chooses a good new project in period 3 (the choice situation is similar in periods 2 and 3). Owing to this choice, the existing project is good in period 4. As a result, the firm chooses a good new project in period 4 (the choice situation is similar in periods 2, 3, and 4). The process

[4] Here *net output* is the value of the output in the period less the value of the repaid principal in the period. In the first period, the net output of the good (bad) project is $Y_G(Y_B)$. In the second period, a good project has a net output of $(1 + Y_G) - 1 = Y_G$ and a bad project has a net output of $(1 + Y_B) - 1 = Y_B$.

continues forever.

The choice situation is similar in each period $t = 2, 3, 4\ldots$Because the existing project is good in each period, both choices yield a constant lifetime profit, π_G and $\Omega_2 - 2p(Y_B - r) + \pi_B$, in each period $t = 2, 3, 4\ldots$ and the incentive constraint is identical in each period. This identical incentive constraint, $\pi_G \geq \Omega_2 - 2p(Y_B - r) + \pi_B$, is met in each period, and the firm chooses a good new project. When the firm chooses a good new project in period t, it acts so that the existing project will be good in the next period. When the firm chooses a good project in period t, it makes the choice of the good project optimal in the next period $t + 1$. Therefore, the firm continues with good projects forever. *QED*.

4. Asynchronous environment: period 1

Given Assumption 5 and Proposition 3, we know that *a firm continues with the existing project type in period 2 and in later periods.* If the existing project is good (bad) in period 2, the firm continues with good (bad) projects in period 2 and thereafter. We need to find the optimal project choice in period 1. We achieve the following result: A firm may avoid risk-shifting in period 1 of the asynchronous environment even if the firm favors risk-shifting in the synchronous environment. Under these circumstances, the firm avoids risk-shifting in each period of the asynchronous environment.

The optimization objective of the firm is the lifetime profit. That objective is different in period 1 than in the later periods. In those, the firm has two projects in each period. In period 1, the firm has only one project. If the firm chooses good projects in each period, the following lifetime profit occurs in period 1:

$$Y_G - r + \delta\pi_G \, . \tag{4.1}$$

In period 1, the firm makes profit $Y_G - r$. The NPV of the future profit is $\delta\pi_G$. If the firm chooses bad projects in each period, the expected lifetime profit is:

$$p(Y_B - r) + \delta p\pi_B \, . \tag{4.2}$$

The project yields expected profit $p(Y_B - r)$ in period 1, and the NPV of the future profit is $\delta p\pi_B$. Again, π_G and π_B are *i*) fixed in each period $t, t \geq 2$, and *ii*) are the same as in the synchronous environment. We examine the optimal project choice in period 1 by comparing (4.1) and (4.2) and find the following:

Proposition 4. *The incentive constraint—a borrower prefers good projects to bad ones—can be met in period 1 of the asynchronous environment even if the incentive constraint is not met in the synchronous environment:* $\pi_B > \pi_G$.

Proof. From (4.1) and (4.2), we get the incentive constraint of period 1 in the asynchronous environment: The firm chooses a good project if:

$$\pi_G \geq \pi_B - [\, p(Y_B - r) - (Y_G - r\,)]. \tag{4.3}$$

The term in the square brackets is positive (Lemma 1). It is possible that the inequality in (4.3) is met even if $\pi_G < \pi_B$. *QED*.

Why do firms avoid risk-shifting in period 1 of the asynchronous environment? In the synchronous environment, the firm starts two projects in period 1. This large capacity makes risk-shifting profitable in period 1. In the asynchronous environment, the firm has one project in period 1 and two projects thereafter. Owing to the small capacity, the expected profit from risk-shifting is low in period 1. Since the firm grows after period 1, it has higher future profits in period 1. The firm will not fail in period 1 and lose the future profits. Hence, the firm will not gamble in period 1.

Propositions 1, 3, and 4 together provide the main result of the paper: even if risk-shifting prevents lending in the synchronous environment, $\pi_B > \pi_G$, the firm may avoid risk-shifting in each period of the asynchronous environment.

Proposition 5. *The incentive constraint—the firm chooses good projects — may be met in periods* $t, t \geq 2$, *of the asynchronous environment even if the constraint is not met in period 1 of the asynchronous environment.*

Proof. In period $t, t \geq 2$, of the asynchronous environment, the firm continues with good projects if $\pi_G \geq \Omega_2 - 2p(Y_B - r) + \pi_B$, or

$$\pi_G \geq \pi_B - [\, p(Y_B - r) - (Y_G - r)\,] - (1 - p)\{Y_G - r - \max[0, Y_G + 1 - 2(1 + r)]\}. \tag{4.4}$$

Owing to the term in the curly brackets being positive, the RHS in (4.4) is smaller than the RHS in (4.3). It is possible that the inequality (4.4) is met even if the inequality (4.3) is not met. *QED*.

Logically, in the asynchronous environment, it is possible that a firm whose existing project is good (that is, in period $t, t \geq 2$) will continue with good projects in the following periods even if the firm prefers a bad project in period 1. In period 1, the firm lacks an existing good project which alleviates the risk-shifting incentives. A firm which has an existing good project in period $t, t \geq 2$, will not gamble and take the risk of losing the profit from the existing good project.

To study the incentive compatible premiums, we introduce an incentive compatible premium for the bad project in period 1 of the asynchronous environment: Δ_1. Inserting $Y_B = Y_G + \Delta_1$ into (4.2) shows that the firm is indifferent to good or bad projects under premium Δ_1 if

$$Y_G - r + \delta \, \frac{2(Y_G - r)}{1 - \delta} \; = \; p(Y_G + \Delta_1 - r) + \delta p \, \frac{2p(Y_G + \Delta_1 - r)}{1 - p\delta} \, . \tag{4.5}$$

Therefore, (4.5) simplifies to:

$$\left[1+\frac{\delta(1-\delta p)}{(1+p\delta)}\right]\Delta_{sync}=\Delta_1. \tag{4.6}$$

Proposition 6. *We have* $\Delta_{async} > \Delta_1 > \Delta_{sync}$.

Proof. We know $\Delta_1 > \Delta_{sync}$ because the term in the square brackets in (4.6) exceeds one. According to (3.11):

$$\Delta_{async}=\frac{2}{1+p\delta}\Delta_{sync}-\frac{(1-p\delta)(1-p)}{(1+p\delta)p}\max[0,Y_G+1-2(1+r)]. \tag{4.7}$$

First, assume that the term in the square brackets in (4.7) is zero. We get the following from (4.6):

$$\Delta_{sync}=\frac{1+p\delta}{2-(1-\delta)(1-p\delta)}\Delta_1. \tag{4.8}$$

Inserting (4.8) into (4.7) creates:

$$\Delta_{async}=\frac{2}{2-(1-\delta)(1-p\delta)}\Delta_1. \tag{4.9}$$

Since the denominator is smaller than two, we have $\Delta_{async} > \Delta_1$. Second, if the term in the square brackets in (4.7) is positive, we can use (4.6) and rewrite (4.7) as:

$$\Delta_1+\frac{(1-p\delta)(1-p)(1+r)}{(1+p\delta)p}=\Delta_{async}. \tag{4.10}$$

Since the second term on the LHS is positive, we have $\Delta_{async} > \Delta_1$. *QED.*

Now $\Delta_{async} > \Delta_1 > \Delta_{sync}$ shows that the incentive compatible output premium for bad projects is the lowest in the synchronous environment (Δ_{sync}) and the highest in the asynchronous environment when the firm has an existing good project (Δ_{async}). Period 1 of the asynchronous environment denotes the intermediate case (Δ_1). Therefore, the parameter set of reputational equilibria is larger when projects are asynchronous rather than synchronous.

Example 2. *Recall Example 1:* $Y_G = 0.0505, r = 0.05, p = 0.25$. *This economy gives* $\Delta_{async} = 0.051 > \Delta_1 = 0.05 > \Delta_{sync} = 0.0315$. *We can find the maximal outputs from the bad project* Y_B *such that a firm chooses good projects. In the synchronous environment, the maximal output is* $Y_B = 0.082$. *Consider the asynchronous environment. If the firm has an existing good project, it will choose a good new project if* Y_B *is at most 0.1015. In the first period of the asynchronous environment, the firm chooses a good project if* Y_B *is at most 0.1005.*

In Example 2, the firm avoids risk-shifting in both environments if the output of the bad project is at most $Y_B = 0.082$. If $0.082 < Y_B \leq$ *0.1005,* risk-shifting prevents lending in the synchronous environment, but the firm avoids risk-shifting in the asynchronous environment. We can express this avoidance using four scenarios. Here Δ is the real size of the output premium: $Y_B = Y_G + \Delta$.

(i) If $\Delta > \Delta_{async}$, then a firm prefers bad projects in both environments. Lenders deny loans.
(ii) If $\Delta_1 < \Delta \leq \Delta_{async}$, then the firm invests in bad projects in the synchronous environment. In the asynchronous environment, the firm continues with good projects forever if the existing project is good in period 2. Unfortunately, this result is fruitless because the firm chooses a bad project in period 1 of the asynchronous environment. Lenders deny loans.
(iii) If $\Delta_{sync} < \Delta \leq \Delta_1$, then the firm invests in bad projects in the synchronous environment and in good projects in each period of the asynchronous environment. Lending is possible only in the asynchronous environment.
(iv) If $\Delta \leq \Delta_{sync}$, then the firm invests in good projects in both environments. Loans are attainable in both environments.

The asynchronous environment has a positive impact on lending in scenario (iii).

5. Ex post monitoring

In this section, lenders can monitor the borrower at no cost and thereby detect the realized project output at the end of the period.[5] Output Y_B reveals risk-shifting and lenders stop lending: A borrower can gamble only for one period.[6] This limitation reduces the profits from risk-shifting. We explore whether the key findings of Sections 2–4 can be generalized to circumstances in which the borrower can hide risk-shifting only for a period. The generalization proves to be realistic.

[5] For ex post monitoring, see Diamond (1984) and Krasa and Villamil (1992). Our assumption – lenders acquire information during the loan period – is in line with the relationship lending literature and is supported by empirical evidence. Roberts and Sufi (2009, p. 160), for example, find that over 90 per cent of long-term debt contracts are renegotiated and make the following conclusions: “Our analysis of what triggers renegotiation reveals that the ***accrual of new information concerning credit quality*** and outside options is a strong predictor of the incidence and outcomes of renegotiation”.

[6] We thank the anonymous referee who mentioned this research idea to us.

Now both an unsuccessful project and output Y_B convey information to lenders and lead to permanent ostracism for the borrower. We begin by examining the synchronous environment.

5.1. The synchronous environment

The incentive constraint—a borrower will invest in good projects—is:

$$\pi_G \geq 2p\max[Y_B + L - (1+r), 0]. \tag{5.1}$$

The LHS denotes the lifetime profit from two good projects. The RHS shows the expected profit from two bad projects. If successful, they produce interim output $2Y_B$ and liquidation proceeds $2L < 2$. Since output $2Y_B$ indicates the choice of bad projects and lenders deny new loans, the firm must liquidate the bad projects and repay the loans, $2(1+r)$. If the bad projects are unsuccessful, lenders learn the choice of bad projects and deny new loans. We assume that risk-shifting prevents lending in the synchronous environment. That is, inequality (5.1) is not met:

$$p[Y_B + L - (1+r)] > \frac{Y_G - r}{1-\delta}. \tag{5.2}$$

The term in the square brackets must be positive.

Let Δ_S label the incentive compatible output premium for the bad project in the synchronous environment. Inserting $Y_B = Y_G + \Delta_S$ into (5.1) gives (when the firm is indifferent between the project types):

$$\Delta_S = \frac{1}{p}\frac{Y_G - r}{1-\delta} - [Y_G + L - (1+r)]. \tag{5.3}$$

If the real size of the output premium Δ, $Y_B = Y_G + \Delta$, exceeds (does not exceed) the incentive compatible output premium Δ_S, then the firm chooses bad (good) projects. In (5.2), we assume that the borrower favors bad projects: $\Delta > \Delta_S$. Next, we study whether the firm favors risk-shifting in the asynchronous environment.

5.2. The asynchronous environment: period $t, t \geq 2$

The firm has an existing good project, and it chooses a new project. If the firm runs two good projects forever rather than choosing a new bad project (that is, the firm has both project types in period t), then the incentive constraint is:

$$\pi_G \geq p\max[Y_B + L + (1+Y_G) - 2(1+r), 0] + (1-p)\max(0, Y_G - 2r - 1). \tag{5.4}$$

With probability p, the new bad project is successful producing Y_B and liquidation proceeds L. The firm must liquidate the bad project because output Y_B indicates the choice of the bad project: lenders deny new loans and require repayments $2(1+r)$. The old, good project expires, producing $1+Y_G$. With probability $1-p$, the bad project is valueless. Then, the old, good project produces $1+Y_G$, lenders deny new loans and require repayments $2(1+r)$.

Let Δ_{At} refer to the incentive compatible output premium for the bad project in the asynchronous environment when the existing project is good: $Y_B = Y_G + \Delta_{At}$. Inserting $Y_B = Y_G + \Delta_{At}$ into (5.4) gives:

$$\Delta_{At} = \Delta_S + \frac{1}{p}\left[\frac{Y_G - r}{1-\delta} - p(Y_G - r) - (1-p)\max(0, Y_G - 2r - 1)\right]. \tag{5.5}$$

Since the term in the square brackets is positive, we have $\Delta_{At} > \Delta_S$. The incentive compatible output premium is higher than in the synchronous environment.

5.3. The asynchronous environment: period 1

A firm does not have an existing project, and it chooses a good new project if:

$$Y_G - r + \delta\pi_G \geq p\max[Y_B + L - (1+r), 0]. \tag{5.6}$$

In period 1, a good project gives $Y_G - r$. The NPV of the future profit is $\delta\pi_G$. In these later periods, the firm has two projects. The RHS shows the expected profit from a bad project. With probability $1-p$, the project is valueless, and lenders observe it and deny new loans. With probability p, the bad project produces Y_B. This output indicates the choice of the bad project, and lenders deny new loans and require repayment $1+r$. The bad project is liquidated. This liquidation gives L. The term in the square brackets is positive, and we can rewrite (5.6) as:

$$\pi_G + \delta\pi_G \geq 2p[Y_B + L - (1+r)]. \tag{5.7}$$

We can draw the following conclusions.

Lemma 6. *The incentive to invest in the bad project is higher in the synchronous environment than in period 1 of the asynchronous environment.*

Proof. As to the profit from bad projects, the RHS of (5.7) is the same as the RHS of (5.1). Consider the profit from good projects.

Since the LHS of (5.7) exceeds the LHS of (5.1), π_G, the firm has more incentives to choose good projects in the asynchronous environment. *QED*.

Lemma 7. *The incentive to invest in the bad project is higher in period 1 of the asynchronous environment than in the latter periods of the asynchronous environment.*

Proof. we can rewrite (5.7)—the incentive constraint of period 1—as:

$$\pi_G \geq p[Y_B + L - (1+r)] + (Y_G - r). \tag{5.8}$$

As to the profit from good projects, the LHS of (5.8) is the same as the LHS in (5.4). Consider the profit from bad projects: The RHS of (5.8) exceeds the RHS of (5.4). The choice of a bad project is more profitable in period 1 than in later periods of the asynchronous environment. *QED*.

Lemmas 6–7 state that the incentive to invest in bad projects is higher in the synchronous environment. In the asynchronous environment, the most difficult incentive problem arises in period 1. These results are the same as in Sections 2–4. Therefore, the findings of Sections 2–4 can be generalized to the case in which the borrower can hide risk-shifting only for a period.

Finally, we compare the incentive compatible premiums. Let Δ_{A1} refer to the incentive compatible output premium for the bad project in the asynchronous environment when the firm has no existing projects: $Y_B = Y_G + \Delta_{A1}$. Inserting $Y_B = Y_G + \Delta_{A1}$ into (5.6) gives:

$$\Delta_{A1} = \Delta_S + \frac{\delta}{p}\frac{Y_G - r}{1-\delta}. \tag{5.9}$$

Therefore,

Proposition 7. *We have* $\Delta_{At} > \Delta_{A1} > \Delta_S$.

Proof. We observe from (5.9) that $\Delta_{A1} > \Delta_S$. Inserting (5.9) into (5.5) gives:

$$\Delta_{At} = \Delta_{A1} + \frac{1-p}{p}[(Y_G - r) - \max(0, Y_G - 2r - 1)]. \tag{5.10}$$

Since the term in the square brackets is positive, we have $\Delta_{At} > \Delta_{A1}$. *QED*.

The result $\Delta_{At} > \Delta_{A1} > \Delta_S$ shows that the incentive compatible premium for bad projects is the highest in period $t, t \geq 2$, of the asynchronous environment, at the intermediate level in period 1 of the asynchronous environment, and lowest in the synchronous environment. The incentive constraint—the borrower chooses good projects—can be met in the asynchronous environment even if risk-shifting prevents lending in the synchronous environment. Logically, in the synchronous environment, a firm chooses two new projects in every other period. Lenders cannot detect the choice of bad projects before the firm's assets consist entirely of bad projects; that is, the firm is already running two bad projects. In the asynchronous environment, the firm invests in one new project in each period and lenders can observe risk-shifting when the firm has only one bad project. Now lenders can react very quickly to nascent risk-shifting and deny new loans. The firm must liquidate both good and bad projects and the liquidations proceeds are allocated to the lenders. Therefore, the expected profit from risk-shifting is low. We provide a numeric example.

Example 3. *Consider economy:* $Y_G = 0.101, r = 0.1, p = 0.5, L = 0.99$.*This economy provides:* $\Delta_{At} = 0.052 > \Delta_{A1} = 0.051 > \Delta_S = 0.031$. *We can find out the maximal outputs from the bad project* Y_B *such that a firm prefers good projects. In the synchronous environment, the maximal output is* $Y_B = 0.132$. *Consider the asynchronous environment. If the firm has an existing good project, it will choose a good new project if* Y_B *is at most 0.153. In period 1 of the asynchronous environment, the firm chooses a good project if* Y_B *is at most 0.152.*

In Example 3, a firm avoids risk-shifting in both environments if the output from the bad project is at most $Y_B = 0.132$. If $0.132 < Y_B \leq 0.152$, risk-shifting prevents lending in the synchronous environment, but the firm avoids risk-shifting in the asynchronous environment. We can express this in detail using four scenarios. Here Δ is the real size of the output premium for bad projects: $Y_B = Y_G + \Delta$.

(i) If $\Delta > \Delta_{At}$, then the firm chooses bad projects in both environments, and lenders deny loans.
(ii) If $\Delta_{A1} < \Delta \leq \Delta_{At}$, then the firm favors bad projects in the synchronous environment. In the asynchronous environment, the firm continues with good projects forever if the existing project is good, and it favors a bad project in period 1. Lenders deny loans.
(iii) If $\Delta_S < \Delta \leq \Delta_{A1}$, then the firm invests in bad projects in the synchronous environment and in good projects in each period of the asynchronous environment. Lending is possible in the asynchronous environment.
(iv) If $\Delta \leq \Delta_S$, then the firm invests in good projects in both environments. Lending is possible in both environments.

6. Conclusions

We consider a borrowing firm that might have an incentive to choose bad (negative NPV) projects when superior good (positive NPV) projects are available. The incentive to do so is the standard one in that bad projects pay more in favorable periods, and the lenders bare the losses during unfavorable periods. We examine an environment with several special features, including the idea than an i.i.d. aggregate shock is present that negatively affects the bad projects but not the good projects. Our objective is to compare two special cases, the first of which we call "synchronous" in which firms choose two 2-period projects together in alternate periods, while in the second, which we call "asynchronous", the firm chooses a new 2-period project in each period. In the asynchronous environment, the firm has an existing project in its first state, and its existence might affect its decisions.

Our findings are that the incentive to invest in the bad project is highest in the synchronous environment, lowest in the asynchronous environment when the firm has an existing good project, and at the intermediate level in period 1 of the asynchronous environment when the firm has no existing projects. Therefore, it is possible that lending is profitable only in the asynchronous environment. We achieve these same findings under two alternative information conditions: Either a project failure indicates that the choice of a project is bad, or the borrower can hide a bad project for a period.

The argument extends to firms that longer project lengths, and the aggregate shock is not essential to the argument. The argument can also be used to investigate effort aversion, input and output diversion problems, and the lender's incentives to interrupt the borrower's bad projects. Niinimäki (2023) utilizes the argument to examine incentives to produce good products.

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Appendix

So far, we have assumed that a good (bad) project produces interim output Y_G (Y_B) after the first period and final output $1+Y_G$ ($1+Y_B$) after the second period. The difference is one: $1+Y_G - Y_G = 1, 1+Y_B - Y_B = 1$. Next, we examine different output levels and their effect on incentives.[7]

A change in good projects

The interim output is $Y_G - \theta \geq r$, and the final output is $1+Y_G + \theta(1+r)$. The lower limit r in $Y_G - \theta \geq r$ ensures that the firm can pay interest on loans. The NPV of a good project is invariant and the outputs of bad projects are unchanged.

Synchronous environment: A firm starts two new projects in every second period. Since the NPV of a good project is invariant and bad projects are changeless, the incentive problem is the same as above. The firm prefers good projects if $\pi_G \geq \pi_B$.

Asynchronous environment: In each period $t, t = 2, 3, 4\ldots$, the output of a firm with two good projects (new and existing) is $Y_G - \theta + 1 + Y_G + \theta(1+r) = 1 + 2Y_G + r\theta$. The larger θ is, the more profitable the good projects are. Since bad projects are changeless, the firm is more (less) willing to do good projects if $\theta > 0 (\theta < 0)$.

In period 1, the NPV of the lifetime profit from the good projects adds up to:

$$\sum_{t=1}^{\infty} \delta^{t-1} \{ Y_G - \theta - r + \delta [Y_G + \theta(1+r) - r] \}. \tag{A.1}$$

Since the NPV of good projects does not change, we can revise (A.1) as:

$$\sum_{t=1}^{\infty} \delta^{t-1} \{ Y_G - r + \delta(Y_G - r)\}. \tag{A.2}$$

That is, θ is insignificant. Good projects yield the same expected profit in period 1 as in the original case of $\theta = 0$.

In sum, the incentive constraint does not change in the synchronous environment and in period 1 of the asynchronous environment. The incentive constraint changes in periods $t = 2, 3, 4\ldots$ of the asynchronous environment: If $\theta > 0$ ($\theta < 0$), the firm is more (less) willing to choose good projects.

A change in bad projects

Assume that good projects are changeless. Consider a change in bad projects: The interim output is $Y_B - \theta \geq r$, and the final output is $1 + Y_B + \theta(1+r)/p$. The NPV of a bad project is invariant.

Synchronous environment: The firm starts two new projects in every second period. Since the NPV of a bad project is invariant and the good projects are changeless, the incentive problem does not change. The firm prefers good projects if $\pi_G \geq \pi_B$.

Asynchronous environment: Consider period $t, t = 2, 3, 4\ldots$ and assume that the firm has invested in good projects. The firm chooses a bad new project when its current holding is a good project and continues with bad projects in the following periods. The firm makes the following expected lifetime profit:

$$p(Y_G - r) + (1-p)\max(0, Y_G - 2r - 1) \tag{A.3}$$

[7] We are grateful to the two anonymous referees who proposed this research subject to us.

$$+\sum_{t=1}^{\infty}\delta^{t-1}p^{t}\quad\{\quad Y_B-\theta-r+\delta p\quad[\qquad Y_B+\theta(1+r)/p-r]\quad\}.$$

This is equal to the incentive constraint when $\theta = 0$. The incentive constraint does not change. The firm has no existing bad projects. Since the NPV of new bad projects does not change, θ has no effect on the incentives to change the project type.

Consider period 1. Again, θ is insignificant. Because θ does not change the NPV of a bad project, the choice of bad projects yields the same expected profit in period 1 as in the original case $\theta = 0$. The idea of the proof is the same as in the context of good projects.

In sum, the changes in the output of bad projects have no effect on the incentive constraints if the changes do not change the NPV of a bad project.

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