Leverage Restrictions in a Business Cycle Model: A Comment

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The paper by Christiano and Ikeda in this volume is one of the first efforts to quantify the welfare gains of leverage constraints in a macroeconomic model with a banking sector. Unlike other models, their answer is that they can be even more desirable when banks hold little equity, and intermediation is depressed. The paper stresses a static force that makes leverage constraints desirable from a second best perspective. This static consideration is the outcome of two frictions: The first is hidden effort on the side of bankers when choosing projects to fund. The second is the presence of incomplete contracts (in the form of limited liability), which prevents depositors from setting contracts that eliminate the hidden effort problem. As a consequence of the lack of optimal contracts, times when banks have little equity will be times when optimal contracts cannot be signed and effort is inefficient.

A restriction on leverage will act as a positive pecuniary externality: it will raise expected profits of banks and alleviate the hidden effort problem. In addition, a leverage constraint limits the extent of potential losses for banks. This improves the moral hazard problem by allowing better contracts. This policy constitutes a Pareto improvement that operates in times when banks are equity poor. To my knowledge, this is one of the few models that provide a rationale for imposing leverage constraints during times of low bank

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equity. This is a scenario that roughly fits the current international regulatory landscape.

This discussion provides the following: In a first section, I offer a static model that illustrates the main force in the model. I deliberately strip off Christiano and Ikeda's model to make the point transparent. I then take a step forward in setting up a planner's problem. This planner's problem highlights why leverage constraints help in the model. I then discuss the dynamic consideration for leverage constraints that I think the authors have overlooked. Finally, I comment on the importance of "being prudential about prudential macroeconomic policy."

1. Main Force

1.1 Environment

To illustrate the main static force in the *CI* model, consider a one-period model. The demographics are composed of two types of players, each populating a unit continuum. Let's call them households and bankers. Households hold a total endowment C of consumption commodities. Every household has the same individual endowment, which we denote by c. Bankers hold a corresponding endowment of N (with n standing for individual endowments). For interpretation, we refer to the bankers' endowment as their net-worth. Both types are risk-neutral and would like to eat as much as possible.

1.2 Technology

Households have access to storage without depreciation. In addition, they have a cost to transfer deposits to bankers $\varphi(d)$. Here, φ satisfies $\varphi' > 0$, $\varphi'' > 0$, $\varphi(0) = 0$. This assumption is important. Although it may seem odd to have a convex technology to transform goods into deposits, this technology yields an upward sloping supply for deposits as a function of expected interest rates that would appear in a dynamic setup with intertemporal substitution. It is simply a shortcut to obtain that curve without involving dynamics. An elastic supply schedule operates at the heart of the pecuniary externality present in the model.

Bankers have access to a linear technology transforming the endowment into consumption goods. However, the technology is risky and characterized by returns in good and bad states: $\bar{R}^G > \bar{R}^{B\prime} > 1$. Bankers can affect the probability from obtaining the high returns by exerting effort. Naturally, the effort or the probability of success has a cost function $C(p) \equiv p^2$.

1.3 Markets

It is convenient to study the model under three possible institutional environments in order to understand what the necessary ingredients of the model are.

(I) Complete Markets: There exists an $\bar{R}$—contingent market for deposits. Thus, we denote the return on deposits by (R_d^G, R_d^B) in good and bad states, and R_d the realized return. Moreover, effort is determined before the realization of returns and there is full commitment on the side of the bankers.

(II) Hidden Effort: Under this market arrangement, there also exists an $\bar{R}$—contingent debt market, but in this case, effort is not contractible. This is an example of hidden, or non-contractible, effort.

(III) Hidden Effort and Limited Liability Constraints: This is the same institutional arrangement as in *(II)* except that now bank losses cannot exceed N.

1.4 Households' Problem

The households choose between deposits d and storage to maximize the end-of-period consumption. Their objective is

$$W^H(c) = \underset{0 \leq d \leq c}{m} (c - \varphi(d)) + E[R_d d].$$

The solution to this problem is

$$E[R_d] = \varphi'(d).$$

so arranging terms delivers

$$E[R_d] = \varphi'(d)$$

where $E[R_d]$ is the expected level of returns given d. Since every household is identical, then we can write this expression in terms of the aggregate amount of supply of deposits D^S:

$$E[R_d] \equiv \varphi'(D^S). \tag{1}$$

Let's now begin defining the bank's problem for the market arrangement (I).

1.5 Bank's Problem in Market I

We setup the banker's problem as choosing

$$W^B(n) = \underset{p\in[0,1],(R_d^G,\,R_d^B),d}{m}(d+n)(p\bar{R}^G + (1-p)\bar{R}^B)$$
$$-d(pR_d^G + (1-p)R_d^B) - \frac{1}{2}p^2$$

subject to

$$pR_d^G + (1-p)R_d^B \geq E[R_d]. \tag{2}$$

There are two things to observe from this problem. First, banks are choosing an effort level that is part of the public information. This follows from the assumption that, under this market arrangement, effort is observable. Second, they choose a contract (R_d^G, R_d^B) pair and a level of deposit demand to maximize profits subject to constraint (2). In constraint (2) it can be interpreted that in order to be able to attract deposits, banks must at least offer an expected return equivalent to the expected market rate. We denote the sum of all deposits that banks demand from households by D^d. We are ready to define an equilibrium.

1.6 Equilibrium in Market I

In an equilibrium, under market arrangement, there are policy functions for households and bankers and an expected market return $E[R_d]$ such that it satisfies:

1. Household's optimally choose d given $E[R_d]$.
2. Banks choose (p, R_d^G, R_d^B, d) optimally given $E[R_d]$.
3. The deposit market clears $D^d = D^S$.
4. $E[R_d]$ is rational and satisfies $pR_d^G + (1-p)R_d^B$ where p, R_d^G, R_d^B are the solutions to the optimal contract.

Analyzing the problem is simplified by defining $S = \bar{R}^G - \bar{R}^B$ and $s = R_d^G - R_d^B$. Here, it is worth noting that for any p chosen, it is always the case that the choice of (p, R_d^G, R_d^B) will satisfy $pR_d^G + (1-p)R_d^B \quad E[R_d]$.[1] Thus, using the principle of optimality,

1. Suppose this is not the case, then there is another contract with lower (R_d^G, R_d^B) such that, at the same level of deposits and p, the contract improves over that candidate solution.

the banker's problem can be written by replacing this equivalence in the objective

$$W^B(n) = \underset{p\in[0,1],d}{m}(d+n)(pS+\bar{R}^B) - dE[R_d] - \frac{1}{2}p^2.$$

An important observation is that the objective is not a function of (R_d^G, R_d^B). Any equilibrium must satisfy

$$(pS+\bar{R}^B) = E[R_d] = \varphi'(D^*) \tag{3}$$

where D^* is the optimal level of deposits or investment. If the condition doesn't hold with equality, d is 0 or ∞. In equilibrium this possibility is ruled out. Moreover, the optimality of effort yields

$$(N+D^*)S \geq * p(N+D^*)S < 1. \tag{4}$$

This set of equations yields a single solution, which is obtained through the following program

$$((N+D^*)S^2 + \bar{R}^B) = \varphi'(D^*)(N+D^*)S < 1p = (N+D^*)\ S$$

or

$$(S+\bar{R}^B) = \varphi'(D^*)(N+D^*)S \geq 1p = 1.$$

We can summarize the system as

$$p = min\{(N+D^*)S,1\} \text{ and } (min\{(N+D^*)S,1\}S + \bar{R}^B) = \varphi'(D^*).$$

This is an equation with a single solution $D^*(N)$, $D^*(N)$ increasing and concave in N. In this risk-neutral environment, naturally, (R_d^G, R_d^B) is indeterminate. In the particular case where $\varphi = 1/2\ D^2$, we have

$$D^*(N) = m\left\{N\frac{S^2}{(1-S^2)} + \frac{\bar{R}^B}{(1-S^2)}, S+\bar{R}^B\right\}.$$

and

$$p^*(N) = m\left\{\frac{NS}{(1-S^2)} + \frac{\bar{R}^B S}{(1-S^2)}, 1\right\}.$$

The welfare theorems apply in this environment. However, it is useful to define a planner's problem subject to the same resource constraint.

$$W^B(C,N) = \underset{D,p}{m}(C, -\varphi(D)) + (N+D)\,(pS + \bar{R}^B) - \frac{1}{2}p^2.$$

It should be obvious that the first order conditions of this problem coincide with (3) and (4), which verify the first welfare theorem. Let's summarize the findings thus far.

Lesson 1: With complete markets and contractible effort, the competitive equilibrium is efficient and is independent of the contract (R_d^G, R_d^B).

There is another observation. Notice that when effort is contractible, limited liability plays no role. The limited liability constraint can be written as

$$(D+N)\bar{R}^B - DR_d^B \geq 0, (D+N)\bar{R}^G - DR_d^G \geq 0. \tag{5}$$

An unconstrained optimum will specify a level of $p^*$and D^* as a function of N. In turn, the value of $E[R_d]$ is pinned down by $\varphi(D^*)$. Thus, in order to implement the first best and imposing the LLC constraint, we need to find a pair R_d^{B*}, R_d^{G*} that jointly satisfies

$$(D^*+N)\bar{R}^B - D^*R_d^{B*} \geq 0 \text{ and } (D^*+N)\bar{R}^G - D^*R_d^{G*} \geq 0.$$

and

$$p^*(R_d^{G*} - R_d^{B*}) + R_d^{B*} = \varphi'(D^*).$$

Can that pair be found? The answer is yes, always. We guess and verify that their exists a pair (x, y) such that (R_d^{B*}, R_d^{G*}) always satisfies the above. To prove, let's conjecture that one such (x, y)

contract is one in which the LLC constraint binds in the bad state. That is: $(D^* + N)\bar{R}^B - D^* x = 0$ or $(1+\tilde{n})\bar{R}^B = x$ for $\tilde{n} = N/D^*$. Now, it had better be the case that $p^*(y - x) + x = \varphi'(D^*)$. So rearranging terms yields

$$y = \frac{\varphi'(D^*)}{p^*} - \frac{(1-p^*)}{p^*}x.$$

We can plug this identity into the LLC for the good state. We obtain

$$(1+\tilde{n})\bar{R}^G > \frac{\varphi'(D^*)}{p^*} - \frac{(1-p^*)}{p^*}(1+\tilde{n})\bar{R}^B$$

and rearranging terms implies

$$(1+\tilde{n})(p^*\bar{R}^G + (1-p^*)\bar{R}^B) > \varphi'(D^*).$$

But recall that the FOC at the optimum implies $(p^*\bar{R}^G + (1-p^*)\bar{R}^B) = \varphi'(D^*)$, so the LLC constraint for the good state is equivalent to

$$(1+\tilde{n})\varphi'(D^*) > \varphi'(D^*)$$

which holds truth for all $N > 0$. We have formally shown the second lesson.

Lesson 2: If effort is contractible, then competitive equilibrium is efficient even if we impose a limited liability constraint on the contract space of (R_d^G, R_d^B). That is, there is a competitive equilibrium that implements the first best allocation.

1.7 Equilibrium in Market II

Let's discard limited liability again but include hidden effort. The presence of hidden effort alters things. When non-verifiable effort is present, we must take into account the incentives of the bankers when employing effort. The reason being that a contract will not be able to implement a prespecified amount of effort if the incentives of the banker aren't taken into consideration. Suppose households and bankers have already agreed on a contract, then, no matter what the prespecified level of effort is, the banker will always choose effort such that it solves

$$W^B(n) = \underset{p\in[0,1]}{m}(d+n)(p\bar{R}^G + (1-p)\bar{R}^B) - d(pR_d^G + (1-p)R_d^B) - \frac{1}{2}p^2.$$

The FOC for this problem is given by

$$(d+n)S - ds = \varphi'(D^*). \tag{6}$$

The equation (6) is the incentive compatibility condition required by this problem.

The revelation principle will require that we specify the Banker's problem including equation (6). Thus, under the institutional environment of hidden effort, we setup the banker's problem as choosing

$$W^B(n) = \underset{p\in[0,1],(R_d^G,\,R_d^B),d}{m}(d+n)(p\bar{R}^G + (1-p)\bar{R}^B) - d(ps + R_d^B) - \frac{1}{2}p^2$$

subject to

$$ps + R_d^B \geq E[R_d]$$

and

$$(d+n)S - ds = \varphi'(D^*).$$

The equilibrium is defined as earlier. Observe that R_d^B is not in the incentive compatibility constraint of the problem, but only the wedge s. So we can reach the same conclusion as before that $ps + R_d^B = E[R_d]$ and that the problem is

$$W^B(n) = \underset{p\in[0,1],(R_d^G,\,R_d^B),d}{m}(d+n)(p\bar{R}^G + (1-p)\bar{R}^B) - dE[R_d] - \frac{1}{2}p^2$$

subject to

$$(d+n)S - ds = \varphi'(D^*).$$

Now, it is easy to show that there exists an optimal contract with $R_d^G = R_d^B = \varphi'(D^*)$ that implements the first best. It may no longer be the only equilibrium—we would need to check this—but at least we can guarantee that hidden effort does not alter whether or not first best allocation is part of an equilibrium set with hidden effort. The intuition is very simple. When $s > 0$ on the margin, the banker is better off exerting less effort than at the optimal level. The reason is that, although a higher probability of success increases total surplus $(d + n)S$, the banker is paying for all the effort, whereby, he has to share the benefits with the household. The only contracts that implement the first best effort are those in which the banker extracts all the benefits of his additional effort.

Recall that under Market I, the efficient allocation was maximizing total aggregate surplus. If bankers choose a contract where $s \neq 0$ they will violate the first order condition for effort. However, this will affect the total surplus for a given level of deposits. If for a given level of deposits, total surplus is lower, either the return to households must fall, or the banker's surplus is lower. There is always room for an improvement of welfare setting $s = 0$. The first best satisfies incentive compatibility at the optimum and makes everyone better off. Thus, we arrive to the following.

Lesson 3: Hidden effort does not introduce any additional inefficiencies as $R_d^G = R_d^B = \varphi'(D^*)$ *implements the first best allocation.*

1.8 Equilibrium in Market III

So far, we have shown that hidden effort and limited liability play no role, independently. We now argue that they not only introduce inefficiencies, but due to a pecuniary externality, will deliver constrained inefficiencies.

The banker's problem is now constrained by the limited liability constraint (LLC)

$$W^B(n) = \underset{p \in [0,1], (R_d^G, R_d^B), d}{m} (d+n)(p\bar{R}^G + (1-p)\bar{R}^B) - d\varphi'(D^*) - \frac{1}{2}p^2$$

subject to

$$(d+n)S - ds = \varphi'(D^*),$$

$$(d+n)\bar{R}^{B*} - dR_d^{B*} \geq 0$$

and $(d+n)\bar{R}^G - dR_d^{G*} \geq 0$

Recall now that the first best can only be achieved if $s=0$, or in other words, if debt is risk free: $R_d^{B*}=R_d^{G*}=\varphi'(D^*)$. Can this contract always be implemented with limited liability? Not any more. To see this, observe that if limited liability constraints bind with risk-free debt, it will be in the low state, where resources are scarce. In the examples I present here, their is a lowest level of that satisfies the LLC in the bad state

$$(1+N^o/D^*(N^o))\bar{R}^B=\varphi'(D^*(N^o)).$$

Thus, for $N<N^o$ it is impossible to satisfy the LLC constraint in the bad state with the first best allocations. The same is true in the more general setup of Christiano and Ikeda. In general, it is the case that the return on deposits in the bad state has to be lower than in the good state. This creates a wedge on the return on deposits in good and bad states s. This positive wedge lowers the incentives of the banker to put effort and lower the return on deposits and loans.

Lesson 4: With hidden effort and limited liability, there is a sufficiently low level of bank net worth such that the first best allocation cannot be implemented. Effort is suboptimal in these cases.

The work of Cristiano and Ikeda highlights the benefits of a restriction on leverage. In essence, with the LLC in place, and hidden effort, we have the market's solution as the solution to the following problem

$$\max_{p\in[0,1],(R_d^G,R_d^B),d}(d+N)(p\bar{R}^G+(1-p)\bar{R}^B)-d\varphi'(D)-\frac{1}{2}p^2$$

IR: $ps+R_d^B\geq E[R_d]$

IC: $(d+N)S-ds=\varphi'(D^c)$

LLC: $(d+N)\bar{R}^B-dR_d^B\geq 0$, $(d+N)\bar{R}^G-dR_d^G\geq 0$

where D^c is taken as given and equals d.

The constrained planner's problem is different because this problem takes into account the scale of the bank, which has effects on the incentives constraints.

$$\max_{p\in[0,1],(R_d^G,R_d^B),d}(d+N)(p\bar{R}^G+(1-p)\bar{R}^B)-d\varphi'(\mathrm{d})-\frac{1}{2}p^2$$

IR: $ps+R_d^B\geq E[R_d]$

IC: $(d+N)S-ds=\varphi'(D^c)$

LLC: $(d+N)\bar{R}^B-DR_d^B\geq 0$, $(d+N)\bar{R}^G-dR_d^G\geq 0$

This is the case of a *pecuniary externality*. In this case, the planner is aware that by restricting the amount of investment, the bank can borrow cheaper. There are two effects. The first is that if banks can borrow cheaper they can offer better contracts. This aspect improves welfare because of the IC constraint and that improves efficiency as more effort can be provided. There is a free lunch. To obtain resources to consume, banks can either obtain costly funding from depositors from a function $\varphi'(D^c)$ or they can exert high effort with deposits. Under the two frictions, in general the market outcome is constrained efficient because at the planner's solution competitive bankers will try to attract more deposits. In equilibrium, market forces will increase the required return to depositors that will degrade incentives to exert effort.

The second effect is that lower leverage itself makes the bank more solvent in the bad state. However, this is not the source of the inefficiency as the banker's problem does take this effect into account. We are ready to summarize the last lesson of the static model.

Lesson 5: It may be desirable to implement leverage constraints if banks have low equity. Leverage constraints will improve a pecuniary externality. This externality enhances the hidden effort problem. Thus, with LLC and hidden effort, the market allocation is constrained inefficiently.

2. Dynamic Considerations

The single-period model discussed misses the dynamic consideration that may make leverage constraints desirable. The version (that I read) of Christiano Ikeda in this volume focuses on only one consideration. The authors noted that problems arise only in states where equity is low. In a competitive environment, as argued earlier, the linearity of returns on bank investment, given a level of p, makes expected returns go to zero. This is not the case when the LLC constraint binds because the model delivers a desirable *monopsony effect* from leverage constraints. With this effect, we expect equity to recover faster.

In my view, Christiano and Ikeda missed a precautionary motive of leverage constraints. The static problem above highlighted that low equity leads to inefficiencies. In a dynamic setup, leverage constraints may also be desirable in good times. That is, even if effort is efficient, it may be desirable to impose leverage constraints: although these constraints may potentially lead to inefficiencies in good times, these inefficiencies may be desirable. The reason is that a planner may wish to trade-off inefficiencies in good times for less inefficiencies in bad times. Leverage constraints are a way to control the size of potential losses of equity. Putting it differently, the planner may wish to smooth market imperfections. I believe this has been the main point of models that suggest countercyclical equity buffers such as Bianchi (2011) or Bigio (2012). We now turn to the comment.

Lesson 6: In a dynamic model, leverage constraints may induce more inefficiencies in "good times" to reduce even more inefficiencies in "bad times." Leverage constraints in "bad times" may reduce competition in financial markets, which may lead to a quicker recovery of bank equity. These forces are the dynamic considerations in the design of leverage constraints.

3. Prudential Macro-Prudential Policy

Although Christiano and Ikeda's paper is full of insights, we should take its lessons with caution. The aftermath of the Great Recession has seen a surge in financial regulation. The capital constraints imposed by Basel-III and banking regulation in Europe have been of particular importance. Although gradual, these constraints are currently binding the actions of banks and are heavily criticized by the financial press.

Christiano and Ikeda is one of the first papers that provide a full-fledged micro-founded model of financial intermediation that prescribes countercyclical capital requirements. In this comment, I argue that microfoundations are not a sufficient condition for policy recommendation. I argue that this model may well fit the data, but there are other microfounded models that can possibly fit the same data, but whose policy recommendations are quite the opposite. These are times where it may pay off to be prudential about macroprudential policy.

To support my view, let's contrast the present model with a model in which the success probability is not a choice by the bank, but rather an increasing deterministic function p of D, the aggregate level of deposits. A model like this can be associated with positive externalities from bank credit. Actually, another of Christiano and Ikeda's papers, Christiano and Ikeda (2012) presents several examples of models that fit this description. Another model that has this property is Bigio (2012).[2]

Assume that there is also limited liability and the rest of the model is identical. Recall that the relative amount of bank equity to the assets of the economy is the only state variable in the model (see also Brunnermeir, He & Krishnamurthy, etc).

Table 1. Sign of Correlation of Observable with Bankers' Net-Worth for both the Christiano-Ikeda Model and the Behavioral Model

$Corr(x,N)$	$C\ I$	*Behavioral*
$E(\Delta Y_t)$	+	+
$V(\Delta Y_t)$	–	–
R	+	+
P_t	+	+

Source: Author's elaboration.

Table 1 describes the correlations delivered by the C&I model and by our behavioral model. These correlations could be used to estimate the parameters of the model in a policy recommendation paper.

Four facts:

1. In both models, the economy's growth rate should be increasing in equity. In the C&I model, the root of the problem is that low net-worth makes limited liability binding, and distorts the optimal contract. In the behavioral model, or in Bigio 2012, low net-worth would force the amount of deposits to fall because of limited liability. Our behavioral assumption immediately implies that the probability of success in good projects should fall.

2. I'm particularly familiar with this model.

2. In models with capital accumulation, the above should map into less growth.
3. If p is bounded by 1/2, for same reason as fact 2, we should expect more volatile output.
4. Depositors are rational. They will expect and earn lower returns when the scale of the banks balance sheet falls.

Although both models have mechanisms that deliver similar testable implications, their policy recommendations are very different. This is like saying that although a model can be immune to the Lucas critique in that they can be used to analyze policy, its policy recommendations may be undesirable. To see why in the context of our example, let's note some facts about leverage constraints. Four facts about leverage constraints follow:

1. Both models, deliver opposite implications for leverage constraints, whereas the Christiano and Ikeda model shows it improves success probabilities, the model with a mechanical rule implies the opposite by construction.
2. In models with capital accumulation, the above should map into different implications for growth.
3. If p is bounded by 1/2, the output volatility will move in different directions.
4. Less deposits means lower interest rates in both models.

I summarize the effects of leverage constraints via table 2.

Table 2. Effects of Leverage Constraints in Times of Low Equity in the Christiano-Ikeda Model and the Behavioral Model

Effects of leverage constraints on	*C I*	*Behavioral*
$E(\Delta Y_t)$	+	–
$V(\Delta Y_t)$	–	+
R	–	–
P_t	+	–

Source: Author's elaboration.

Clearly, both models deliver different policy implications. To identify either model, an econometric methodology would require observing *effort*. Since effort is unobservable by assumption, the way to distinguish either model would be through a natural experiment. Exploring this idea goes beyond this discussion, but I believe understanding the right frictions banks face is a macroeconomic priority. Summing up we arrive at the following.

Lesson 7. Two equally well-microfounded models may prescribe different policy implications. We ought to be prudential about macro-prudential policy.

4. Summarizing Ideas

Christiano and Ikeda's paper belongs to a growing literature placing financial intermediation at the center of a macroeconomic model. There are very few macroeconomic models that explore leverage constraints. The mechanism in the paper operates by having a limited liability constraint that activates a moral-hazard problem when limited liability can not be met. This type of work is very important, especially in light of an even stricter financial regulation that banks in Europe and the U.S. are facing: BASEL-III, Dodd-Frank etc. It is no surprise that popular writings such as The Economist or The Wall Street Journal continuously place this topic among their headlines. This model supports the capital requirements that are in place nowadays. However, I have argued that other models, with identical testable implications, can deliver opposite recommendations. Regulators should be prudential about macro-prudential policies. We do not want to live in a world where regulators do in times of skinny cows, what they should have done when cows were fat.

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