Volatility, R&D, and Growth

Philippe Aghion — Harvard and NBER

George-Marios Angeletos — MIT and NBER

Abhijit Banerjee — MIT and NBER

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Abstract

This paper investigates the effect of credit constraints on the cyclical behavior of the composition of investment and the implications for growth and volatility. We first consider a simple model in which firms engage in two types of investment, short-horizon productive projects (capital) and long-horizon growth-promoting projects (R&D). Under complete markets, R&D tends to be countercyclical, thus mitigating volatility, and mean growth tends to increase with volatility. These relations are reversed when firms face tight borrowing constraints. R&D becomes procyclical, thus amplifying volatility, and mean growth tends to decrease with volatility. Moreover, the tighter the credit constraints, the higher the sensitivity of R&D and growth to exogenous shocks. We next investigate empirically the predictions of the model. We find that the level of financial development indeed explains the relation between growth and volatility, the sensitivity of growth to exogenous shocks, and the cyclical behavior of R&D, well in accordance with our theoretical predictions.

1 Introduction

Motivation

- early RBC theory $\longrightarrow$ dichotomy between long-run growth and business cycle
- data (e.g. Ramey and Ramey, 1995) $\longrightarrow$ volatility has a negative effect on growth
- endogenous growth theory (AK, precautionary savings, investment risk) $\longrightarrow$ ambiguous effect of volatility on growth, via savings/investment
- data (e.g. Ramey and Ramey, 1995) $\longrightarrow$ most of the effect via a different channel, not savings/investment

This Paper

- transmission channel = composition of investment $\times$ credit markets
- volatility $\longrightarrow$ composition of investment $\longrightarrow$ TFP, growth, and volatility
- differential effects depending on credit markets
- a theory for the Solow residual

The Model

- two types of investment
- type 1: "investment in capital"
  - ▶ short horizon ▶ little time-to-build ▶ low adjustment costs
- type 2: "investment in R&D"
  - ▶ long horizon ▶ more time-to-build ▶ high adjustment costs

- endogenous TFP growth
  - ▶ driven by R&D investment

Results

- complete markets ⇒
  - ▶ type-2 investment (R&D) countercyclical
  - ▶ mitigates business cycle
  - ▶ mean growth insensitive to volatility
- incomplete markets ⇒
  - ▶ type-2 investment (R&D) procyclical
  - ▶ amplifies business cycle
  - ▶ mean growth decreases with volatility

2 The Basic framework

In any given period t, the economy is populated by overlapping generations of two-period lived entrepreneurs. In the first period of her life, an entrepreneur decides how much to invest in short-run or in long-run projects (e.g, think of physical capital versus R&D investments). In the second period of her life, and provided she has survived until then, the entrepreneur produces using the long-term capital investment made in the first period. Also, at the end of the second period the entrepreneur consumes her total life-time income. All individuals are risk-neutral and do not discount the future.

2.1 Aggregate Productivity

Let T_t denote the aggregate stock of knowledge, A_t the aggregate productivity, and z_t the aggregate level of R&D, all as of period t. In the absence of aggregate uncertainty, productivity would coincide with the level of knowledge ($A_t = T_t$). We introduce aggregate uncertainty in the model by letting

$$\ln A_t = \ln T_t + \ln a_t \tag{1}$$

where a_t represents an exogenous aggregate productivity (or demand) shock in period t. We specify

$$\ln a_t = \rho \ln a_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim \mathcal{N}\left(-\sigma^2/2, \sigma^2\right),$$

so that $\rho \in [0, 1)$ and $\sigma > 0$ measure the persistence and the volatility of the exogenous aggregate shock. Note that T_t can be intrepreted as the "trend" in productivity. Unlike the RBC framework, however, T_t will be determined endogenously, in a way specified later.

2.2 The Individual Entrepreneur

There is a continuum of mass one of agents (entrepreneurs) born in each period t, indexed by i and uniformly distributed over $[0, 1]$. Each agent lives for two periods. She makes investment choices in the first period, produces in both the first and the second period, and consumes only in the second period. His lifespan is illustrated in Figure 1 and explained below.

Consider an entrepreneur born in period t. In the beginning of life, the entrepreneur receives an endowment that is proportional to the inheritted level of knowledge: $W_t^i = wT_t$ for some $w > 0$. In the first period of her life, the entrepreneur must decide on how to allocate her initial endowment between short-run investments, K_t^i, long-term investments, Z_t^i, and savings in the riskless bond, B_t^i. Her budget constraint is thus given by

$$K_t^i + Z_t^i + B_t^i \leq W_t^i.$$

To ensure a balanced-growth path, we assume that the costs of capital and R&D investments, like the initial endowment of each entrepreneur, are proportional to T_t, and denote with $k_t^i = K_t^i/T_t$, $z_t^i = Z_t^i/T_t$, and $b_t^i = B_t^i/T_t$ the "detrended" levels of capital, R&D, and bonds holdings. The initial budget constraint thus reduces to

$$k_t^i + z_t^i + b_t^i \leq w.$$

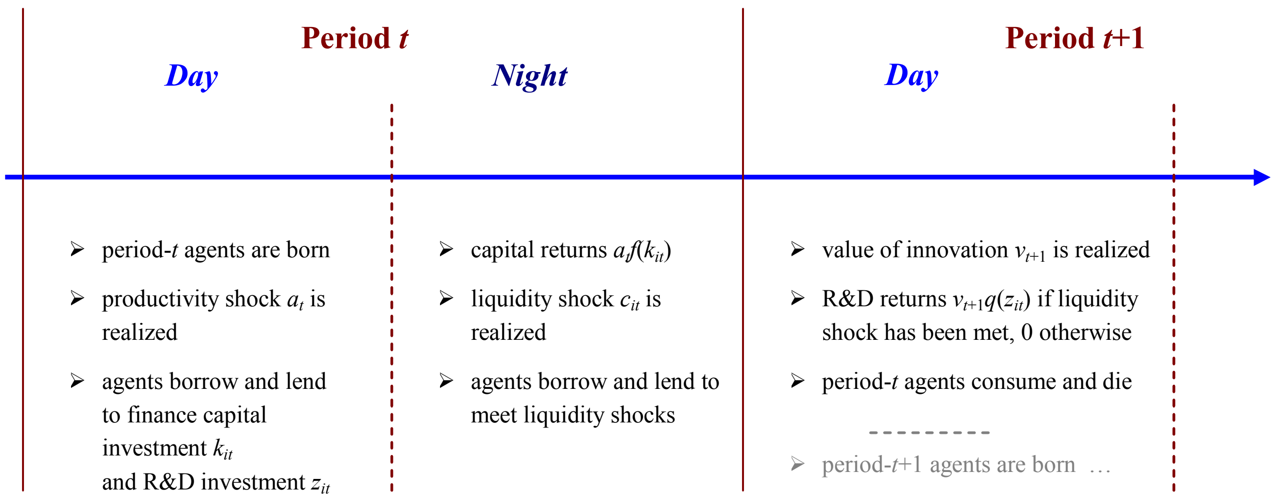

Figure 1: The life of an entrepreneur.

Short-run capital investment at date t generates income $\Pi_t^i = A_t \pi(k_t^i)$ at the same date. The production function π is "neoclassical", that is, it satisfies $\pi' > 0 > \pi''$, $\pi'(0) = \infty$, and $\pi'(\infty) \leq 0$.

Long-term investment at date t generates income at date $t+1$ only if the firm has met a liquidity shock at the end of period t. In particular, the succesful implementation of this innovation requires that the entrepreneur incurs a positive cost $C_t^i = c_t^i T_t$ at the end of the period. For simplicity, we take c_t^i to be i.i.d. across entrepreneurs and across periods, with c.d.f. F and positive density f over $\mathbb{R}_+$. Conditional on paying this cost, the income generated by long-term investment is $\Pi_{t+1}^i = V_{t+1} q(z_t^i) + C_t^i$, where $q(z_t^i)$ can be interpreted as the probability that R&D is successful and V_{t+1} as the value of a new innovation. The function q is also "neoclassical", that is, it satisfies $q' > 0 > q''$, $q'(0) = \infty$, and $q'(\infty) \leq 0$.

The fact that Π_{t+1}^i includes C_t^i means that the net return to R&D, $V_{t+1} q(z_t^i)$, is not affected by the survival cost and therefore it is always optimal to pay the surival cost – but whether the firm will be able to do so will depend on the efficacy of credit markets. In other words, C_t^i represents a pure liquidity shock.

The entrepreneur is risk neutral and consumes only in the last period of her life. Expected life-time utility is thus given by $\mathbb{E}_t[W_{t+1}^i]$, where W_{t+1}^i is her final-period wealth. The latter is given by

$$W_{t+1}^i = \Pi_t^i + \Pi_{t+1}^i \mathbb{I}_t^i + (1 + r_t) B_t^i,$$

where $\mathbb{I}_t^i = 1$ if the firm survives to period $t+1$ and $\mathbb{I}_t^i = 0$ otherwise. Normalizing by the level of technology, final-period wealth is given by

$$w_{t+1}^i = a_t \pi(k_t^i) + v_{t+1} q(z_t^i) \mathbb{I}_t^i + (1 + r_t) b_t^i,$$

where $w_{t+1}^i = W_{t+1}^i / T_t$ and $v_{t+1} = V_{t+1} / T_t$.

We finally need to specify the value of a new innovation. What is important for our results is only that the return to R&D is less procyclical than the return to capital. This is true in our model if and only if the commovement of $v_{t+1} = V_{t+1}/T_t$ and $a_t = A_t/T_t$ over the business cycle is less than perfect, which is necessarily the case as long as the productivity shock is less than fully persistent and the value of innovation represents a present value of returns over a horizon extending beyond period t. A tractable example would be $V_{t+1} = A_{t+1}$, in which case $\ln v_{t+1} = \rho \ln a_t + \varepsilon_{t+1}$. A perhaps more plausible but less tractable specification would be $V_{t+1} = \mathbb{E}_{t+1} \sum_{j=1}^{T} M_{t+j} A_{t+j}$, where T represents the horizon of a new innovation and M_{t+j} is the market discount factor. To retain tractability, we let

$$\ln v_{t+1} = \theta \ln a_t + \xi_{t+1},$$

where θ measures the procyclicality of the value of R&D and $\xi_{t+1} \sim \mathcal{N}\left(-\sigma_v^2/2, \sigma_v^2\right)$ represents a random shock in the value of R&D. It follows that $\mathbb{E}_t v_{t+1} = (a_t)^{\theta}$. Naturally, we assume $\theta = \theta(\rho)$, where $\theta(\rho)$ is increasing in ρ with $0 \leq \theta(0) < \theta(1) \leq 1$.

2.3 Credit Markets

Credit markets open twice every period. The "day" market takes place in the beginning of the period, before the realization of the liquidity shocks. The "overnight" market takes place in the end of the period, after the realization of the liquidity shocks.

During the day, the entrepreneur can borrow only up to m times her initial wealth. That is, he faces the constraint $B_{t+1}^i \geq -mW_t^i$, or equivalently

$$k_t^i + z_t^i \leq \mu w,$$

where $\mu = 1 + m$. Similarly, during the night, the entrepreneur can borrow no more than μ times her available wealth for the purpose of covering the liquidity shock. Therefore, the firm survives if and only if

$$c_t^i \leq x_t^i \equiv \mu \left[a_t \pi(k_t^i) + (1 + r_t)\, b_t^i \right].$$

For the purpose of comparative statics, it will be useful to approximate the probability of survival, $p_t^i \equiv \Pr\left(c_t^i \leq x_t^i\right) \equiv F\left(x_t^i\right)$, by

$$\ln p_t^i \approx \phi \ln x_t^i,$$

where ϕ is the (local) elasticity of F. The parameters μ and ϕ then parametrize the tightness of credit constraints: $\mu = \infty$ corresponds to perfect credit markets, while $\mu = 1$ corresponds to no credit markets. Similarly, $\phi = 0$ means that the probability of survival is independent of wealth, whereas a large ϕ corresponds to a high wealth sensitivity of the survival probability.

Finally, we close the model by assuming that no storage is available during the day, whereas overnight storage is feasible at rate one-to-one. The latter implies that the "overnight" interest rate is bounded below by 0. We finally restrict the parameters so that the equilibrium satisfies

$$\int_i \left[c_t^i \mathbb{I}_t^i - a_t \pi\left(k_t^i\right)\right] \leq 0,$$

which ensures that the "overnight" interest rate is always zero. On the other hand, the "day" interest rate r_t adjusts so that the excess aggregate demand for the riskless bond in the day market is zero. This is equivalent to imposing the resource constraint:

$$\int_i \left[k_t^i + z_t^i\right] = w.$$

2.4 Technological Growth

To close the model, we need to specify the dynamics of T_t. For simplicity, we assume that the rate of accumulation of knowledge is proportional to the aggregate rate of innovation in the economy:

$$\ln T_{t+1} - \ln T_t = \gamma \int q(z_t^i) \mathbb{I}_t^i,$$

where $\mathbb{I}_t^i$ is the index that takes the value 1 if firm i implements an innovation and 0 otherwise, and $\gamma > 0$.

3 R&D and Capital Investment

3.1 Complete Markets

Consider an entrepreneur i born at date t. She will choose $\left(k_t^i, z_t^i, b_t^i\right)$ to solve

$$\max_{k,z}\{a_t\pi(k) + \mathbb{E}_t v_{t+1} q(z) + (1+r_t)b\}$$

subject to the budget constraint

$$k + z + b \leq w.$$

Obviously, all entrepreneures make identical choices. The first-order conditions give

$$a_t\pi'(k_t) = 1 + r_t,$$

$$\mathbb{E}_t v_{t+1} q'(z_t) = 1 + r_t.$$

It follows that

$$\frac{q'(z_t)}{\pi'(k_t)} = \frac{a_t}{\mathbb{E}_t v_{t+1}} = a_t^{1-\theta}, \tag{2}$$

which implies (since $\pi'' < 0$ and $q'' < 0$) that z_t is less procyclical than k_t. Moreover, in equilibrium r_t adjusts so that

$$k_t + z_t = w. \tag{3}$$

We conclude that k_t is procyclical and z_t is countercyclical.

Proposition 1 *Under complete markets, the share of capital investment is procyclical, whereas the share of R&D is countercyclical. The share of R&D is more countercyclical the less persistent the aggregate shocks, or the longer the horizon of long-term investments.*

Current profits are more sensitive to the contemporaneous state of the economy than the profitability of long-term investments. It follows then that k_t should be procyclical than z_t. In particular, during a recession agents expect that production in the short run will not be very profitable, because the recession is likely to persist for some time. On the other hand, the value of long-term (R&D) investments is more or less independent of the phase of the business cycle, because these create profitable opportunities for the long-run, for which the current state of the cycle has low predictive power. If aggregate shocks were not persistent at all, so that $\mathbb{E}_t a_{t+1}$ is constant over the business cycle, the demand for long-term investment z_t would be invariant over the business cycle for given interest rates. But since interest rates are procyclical, z_t is countercyclical in equilibrium. Introducing persistence in the aggregate shock induces procyclicality in the demand for z_t, and therefore dampens the countercycality of the equilibrium level of z_t. Nonetheless, as long as productivity growth is mean-reverting, the demand for z_t is less procyclical than the demand for k_t, and therefore less procyclical than r_t, so that the equilibrium level of z_t remains countercyclical.

Example Suppose $\pi(k) = k^\alpha$ and $q(z) = z^\alpha$, $0 < \alpha < 1$. Condition (2) then reduces to $(k_t/z_t)^{1-\alpha} = a_t^{1-\theta}$, which together with (3) implies

$$k_t = \frac{a_t^\eta}{1+a_t^\eta} w \quad \text{and} \quad z_t = \frac{1}{1+a_t^\eta} w,$$

where $\eta = (1-\theta)/(1-\alpha) > 0$.

3.2 Incomplete Markets

Credit constraints limit entrepreneurs' borrowing capacity to a finite multiple μ of their current wealth in both periods of their lifetime. At the ex ante stage, the investment choices of firm i are contrained by

$$k_t^i + z_t^i \leq \mu w.$$

At the ex post stage, the firm will implement a successful innovation if and only if

$$c_t^i \leq \mu \left[a_t \pi(k_t^i) + (1+r_t)\, b_t^i \right],$$

where $a_t \pi(k_t^i) + (1+r_t) b_t^i$ is the net wealth accumulated during the first production period.

Given the above two constraints, a new entrepreneur born at date t will choose her investment profile (k_t^i, z_t^i) so as to solve

$$\max_{k,z} \{ a_t \pi(k) + \mathbb{E}_t a_{t+1} q(z) F\left(\mu \left[a_t \pi(k) + (1+r_t) b \right]\right) + (1+r_t) b \}$$

$$s.t. \qquad k + z + b \leq w$$

The first-order conditions for this problem give

$$a_t\pi'(k_t) + \mathbb{E}_t v_{t+1} q(z_t) f(\cdot)\,\mu\left[a_t\pi'(k_t) - (1+r_t)\right] = 1 + r_t,$$
$$\mathbb{E}_t v_{t+1} q'(z_t) F(\cdot) - \mathbb{E}_t v_{t+1} q(z_t) f(\cdot)\,\mu\,(1+r_t) = 1 + r_t.$$

The condition for k_t is obviously satisfied at

$$a_t\pi'(k_t) = 1 + r_t, \tag{4}$$

which implies that the demand for k_t is not affected by credit constraints. The condition for z_t, on the other hand, reduces to

$$\mathbb{E}_t v_{t+1} q'(z_t) = (1+r_t)\left[\frac{1 + \mathbb{E}_t v_{t+1} q(z_t) f(\cdot)\,\mu}{F(\cdot)}\right]. \tag{5}$$

Since the term in brackets is higher than one, it follows that the demand for z_t is necessarily lower than under complete markets. In equilibrium, the interest rate r_t still adjusts so that $b_t = 0$ and $k_t + z_t = w$. It follows that

Proposition 2 *For any realization a_t, incomplete markets lead to a lower interest rate r_t, a higher capital investment k_t, and a lower R&D z_t as compared to complete markets.*

Let $\phi(x) \equiv f(x)\,x/F(x)$ denotes the elasticity of F. Combining (4) and (5), and using the fact that $b_t = 0$ in equilibrium, we infer

$$\begin{aligned}\frac{q'(z_t)}{\pi'(k_t)} &= \frac{a_t}{\mathbb{E}_t v_{t+1}}\left[\frac{1}{F(\cdot)} + \frac{\mathbb{E}_t v_{t+1} q(z_t)\phi(\cdot)}{a_t\pi(k_t)}\right] \\ &= \frac{a_t^{1-\theta}}{F(\mu a_t\pi(k_t))} + \phi(\mu a_t\pi(k_t))\,\frac{q(z_t)}{\pi(k_t)}.\end{aligned}$$

Assuming that ϕ is relatively stable over the business cycle, and since the probability of survival $F(\mu a_t\pi(k_t))$ is procyclical, we infer that the ratio z_t/k_t is necessarily less countercyclical than under complete markets, and may even turn to procyclical. Indeed, approximating $\ln F(x) \approx \phi \ln x$ for some constant ϕ, the above reduces to

$$\frac{q'(z_t)}{\pi'(k_t)} \approx \frac{a_t^{1-\theta-\phi}}{[\mu\pi(k_t)]^{\phi}} + \phi\frac{q(z_t)}{\pi(k_t)} \tag{6}$$

It follows that z_t/k_t is procyclical if and only if $\phi > 1 - \theta$.[1] Moreover, the procyclicality of z_t increases with a higher ϕ, a lower μ, or a lower θ (or lower ρ). Recall that μ and ϕ parametrize how tight the credit constraints are. Indeed, z_t falls with either a reduction in μ or an increase in ϕ. We thus conclude

Proposition 3 *Under sufficiently incomplete markets, the share of R&D z_t becomes procyclical, and the share of capital investment k_t becomes countercyclical. z_t is less procyclical the more complete the markets, the less persistent the shocks, or the longer the horizon of long-term investment.*

Example The following three figures illustrate the effect of credit constraints on the level of R&D, the cyclical variation of R&D, and the probability of survival. We assume that the distribution of c is lognormal, in which case of course the elasticity ϕ is not constant. We also assume $\pi(k) = k^\alpha$, $q(z) = z^\alpha$, $\alpha = 1/3$, and let μ vary between 1 (meaning no credit) and 5 (meaning a credit line as large as four times the entrepreneur's income). Figure 2 depicts the equilibrium level of z_t, evaluated at the mean productivity level ($a_t = 1$). Figure 3 depicts the equilibrium cyclical elasticity of z_t (also evaluated at $a_t = 1$). Finally, Figure 4 depicts the equilibrium probability of meeting the liquidity shock (also evaluated at $a_t = 1$). We see that a reduction in μ leads to lower R&D, more procyclical R&D, and lower probability of meeting the liquidity cost.

4 Volatility and Growth

4.1 Complete Markets

The growth rate of technology is

$$g_t \equiv \ln T_{t+1} - \ln T_t = \gamma q\left(z(a_t)\right),$$

where $z(a_t)$ is the (complete-markets) equilibrium level of R&D. Since $z(.)$ is monotonic, a higher variance in a_t implies a higher volatility in g_t. On the other hand, the effect of a

[1] In the case of a (locally) uniform distribution, $\phi = 1$ and this is automatically satisfied.

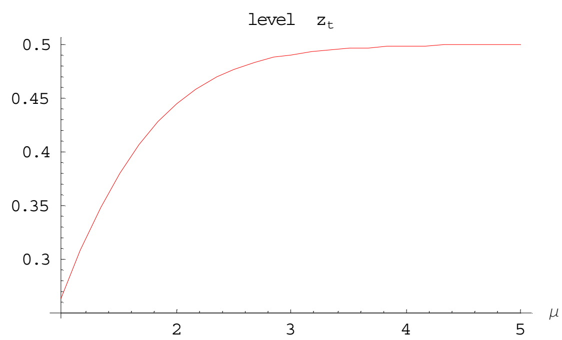

Figure 2: The effect of incomplete markets on the level of R&D.

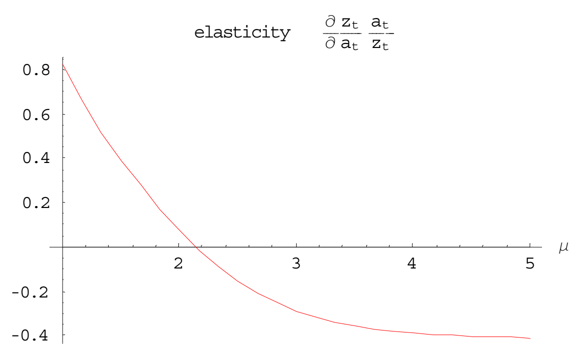

Figure 3: The effect of incomplete markets on the cyclical elasticity of R&D.

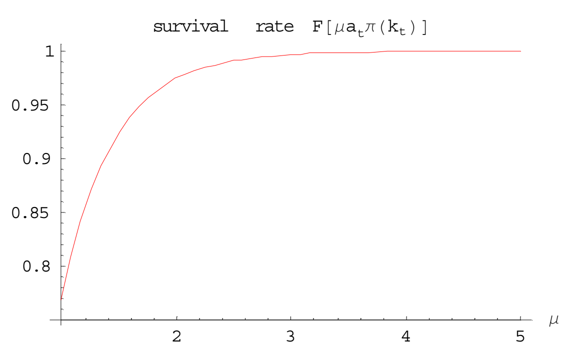

Figure 4: The effect of incomplete markets on the probability of meeting the liquidity risk.

higher variance in a_t on the mean growth rate depends on the curvature of $q(.)$ and $z(.)$. In general, $z(.)$ may have both convex and concave segments. Note, however, that $z(a)$ is decreasing in a and satisfies the Inada conditions $\lim_{a\to 0} z(a) = w$ and $\lim_{a\to\infty} z(a) = 0$. It follows that on average $z(.)$ is convex. Therefore, an increase in the variance of a_t is likely to increase the mean rate of R&D. This is clear in the Cobb-Douglas example we gave in the previous section, in which case it can be shown that $z''(a) < 0$ at the mean value of a. The concavity of $q(.)$ may moderate the effect on mean growth. Nevertheless, g_t remains bounded and decreasing in a_t, with $g_t \to q(w)$ as $a_t \to 0$ and $g_t \to 0$ and $a_t \to \infty$. Hence, although the effect of volatility on growth is generally ambiguous, we conclude that

Proposition 4 *Under complete markets, higher volatility is likely to be associated with higher mean growth.*

Moreover, since $z(a_t)$ is countercyclical, we have

Proposition 5 *Under complete markets, technological growth is likely to be countercyclical and therefore to mitigate the business cycle.*

4.2 Inomplete Markets

The growth rate of technology now given by

$$g_t \equiv \ln T_{t+1} - \ln T_t = \gamma q\left(z(a_t)\right)\delta(a_t)$$

where $z(a_t)$ is the (incomplete-markets) equilibrium level of R&D and

$$\delta(a_t) \equiv F\left(\mu a_t \pi\left(w - z(a_t)\right)\right)$$

is the equilibrium probability of survival. As we discussed before, when μ is sufficiently low, $z(a_t)$ is likely to be increasing in a_t. Since $z(a_t)$ is bounded between 0 and w, it is also likely to be on average concave in a_t. Since $q(z)$ is concave in z, $q(z(a_t))$ is even more likely to be concave in a_t. Similarly, $\delta\left(a_t\right)$ is increasing a_t and bounded between 0 and 1, which suggests that $\delta(a_t)$ is also likely to be on average concave in a_t. The mean of g_t thus tends to fall with an increase in the variance of a_t.

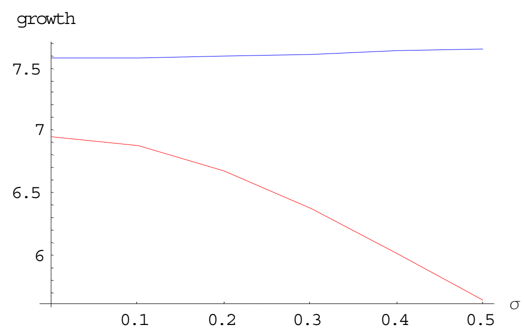

Figure 5: The effect of exogenous productivity risk on growth (blue line = complete markets, red line = incomplete markets)

Proposition 6 *Under incomplete markets, higher volatility is likely to be associated with lower mean growth, and all the more so the tighter the credit constraints.*

Moreover, since both $z(a_t)$ and $\delta(a_t)$ are procyclical, we have

Proposition 7 *Under incomplete markets, technological growth is likely to be procyclical and therefore to amplify the business cycle.*

Example Figures 5-7 illustrate the effect of credit constraints on the mean growth rate, the level of volatility, and the relation between volatility and growth, for the same example as the one used in Figures 2-4. Figure 5 shows how the mean of the growth rate of the economy ($growth$) varies with the standard deviation of the exogenous shock (σ). Figure 6 shows how the standard deviation of the growth rate of the economy (vol) varies with the standard deviation of the exogenous shock (σ). Finally, figure 7 depicts the implied relation between $growth$ and vol as σ varies exogenously. The blue lines represents complete markets, wheres that red lines correspond to incomplete markets. For any level of σ, incomplete markets are associated with lower growth and higher volatility than complete markets. Moreover, the relation between growth and volatility is almost flat (slightly increasing) under complete markets, but strongly negative under incomplete markets.

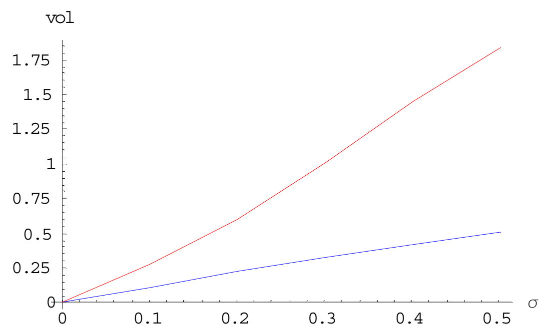

Figure 6: The effect of exogenous productivity risk on aggregate volatility (blue line = complete markets, red line = incomplete markets)

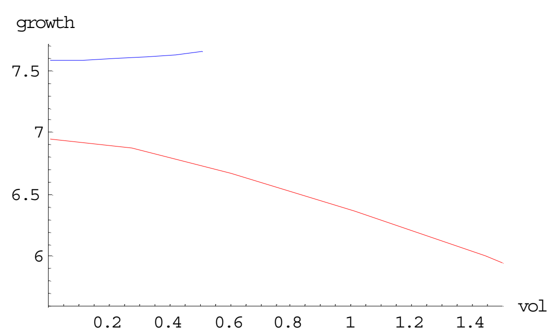

Figure 7: The relation between growth and volatility (blue line = complete markets, red line = incomplete markets)

Example Suppose linear technologies, a random walk for the exogenous shock, and a (locally) uniform distribution for the survival cost: $\pi(k) = k$, $q(z) = \lambda z$, and $\rho = \phi = 1$. Then, (6) reduces to

$$\lambda = \frac{1}{\mu a_t k_t} + \phi \frac{\lambda z_t}{k_t},$$

which together with $k_t = w - z_t$ implies that the equilibrium level of R&D is given by

$$z(a_t) = \frac{\lambda w - (\mu a_t)^{-1}}{1 + \lambda}.$$

It follows that $z'(a) > 0 > z''(a)$, as well as that z increases with μ. Next, the probability of survival is given by $F(\mu a_t \pi(k_t))$, or

$$\delta(a_t) = \frac{1 + \mu a_t w}{1 + \lambda},$$

which is increasing in a_t and μ. Finally, the growth rate of the economy is given by

$$g(a_t) = \gamma q\left(z(a_t)\right) \delta(a_t) = \gamma \lambda \frac{[1 + \mu a_t w][\lambda w - (\mu a_t)^{-1}]}{(1 + \lambda)^2},$$

and it is easy to check that $g'(a) > 0 > g''(a)$, as well as that $g(a)$ increases with μ. The concavity of g implies a negative relation between volatility and growth. What is more, it is easy to show that $\partial g''(a)/\partial \mu < 0$ and $\partial g''(a)/\partial \mu > 0$, which means that $g(a)$ becomes both more sensitive to a and more concave in a as credit constraint become tighter. By implication, the more incomplete markets are, the stronger the negative effect of volatility on mean growth.

4.3 R&D Spillovers

In the previous section, we abstracted from any kind of spillovers in R&D activity, in order to highlight the direct implications of incomplete markets. But now let us suppose that the growth rate at the individual level increases with the aggregate level of R&D.

In particular, suppose that the value of innovation in period $t+1$ is proportional to the level of technology in period $t+1$ rather than that in period t :

$$V_{t+1} = \widetilde{\upsilon}_{t+1} T_{t+1} \quad \text{and} \quad \widetilde{\upsilon}_{t+1} = \theta \ln a_t + \upsilon_{t+1},$$

where $\theta = \theta(\rho) \in (0, \rho]$ again measures the procyclicality in the value of innovation and υ_{t+1}. It follows that the final wealth of the firm is now given by

$$w_{t+1}^i \equiv \frac{W_{t+1}^i}{T_t} = a_t \pi(k_t^i) + v_{t+1} q(z_t^i) \mathbb{I}_t^i + (1 + r_t) b_t^i,$$

where $v_{t+1} \equiv V_{t+1}/T_t$ now satisfies

$$\ln v_{t+1} = \gamma z(a_t) + \theta \ln a_t + \upsilon_{t+1}$$

That is, the normalized value of an innovation for the individual now increases with the aggregate rate of innovation. This spillover generates a macroeconomic complementarity in R&D investment: The optimal level of R&D for the individual is a positive function of the anticipated aggregate growth rate. In general equilibrium, the aggregate growth rate is in turn a positive function of how much R&D individual do. But, how does this macroeconomic complementarity interact with the business cycle?

Under complete markets, R&D and technological growth tend to be countercyclical because of the opportunity-cost effect. Therefore, if the economy enters a recession, agents anticipate that innovation and technological progress will be *high* in the near future. In the presence of an aggregate demand externality or knowledge spillover, the anticipation of higher growth in the future feeds back to an even higher R&D in the present. Therefore, with complete markets, the macroeconomic complementarity in R&D reinforces the *countercyclicality* of technological growth and further *mitigates* the business cycle.

Things are quite different when firms are credit-constrained. As we discussed, R&D and technological growth become procyclical. When the economy enters a recession, agents anticipate that innovation and technological progress will be *low* in the near future. The anticipation of lower growth in the future now feeds back to an even lower incentive to do R&D in the present. Therefore, with incomplete markets, the macroeconomic complementarity in R&D reinforces the *procyclicality* of technlogical growth and thereby further *amplifies* the business cycle.

Proposition 8 *The existence of knowledge externalities increases the countercyclicality of technological growth and further mitigates the business cycle when markets are complete,* *whereas it increases the procyclicality of technological growth and further amplifies the business cycle when markets are sufficiently incomplete.*

5 Empirical Analysis

Before we proceed to the empirical part of the paper, let us briefly state our main conjectures as they emerge from the theoretical analysis in the previous sections:

1. Low levels of financial development predict low R&D, low growth, and high volatility. This is subject to reverse causality.

2. The level of financial development explains the slope of the relation between aggregate volatility and mean growth (or mean R&D investment). When firms face tigher credit constraints, the relation becomes more negative (or less positive). Less likely to suffer from reverse causality?

3. The level of financial development predicts the sensitivity of growth to past exogenous shocks. When firms face tighter constraints, growth becomes more sensitive to exogenous shocks, especially lagged ones. (amplification)

4. The level of financial development predicts the cyclicality of R&D and other knowledge-intensive investments. As a fraction of GDP or total investment, R&D tends to be countercyclical in the absence of credit constraints, but becomes increasingly procyclical as credit constraints tighten.

....

5.1 Growth and Volatility

We start by examining the relation between volatility and growth in the cross-section of countries in the period 1960-1995.

Table 1 repeats the basic cross-country results of Ramey and Ramey (1995). The effect of volatility on growth is generally negative, although it is unstable across different specifications. Moreover, the effect of volatility on growth is relatively insensitive to whether we control for the average rate of investment rate. The link from volatility to growth thus does not appear to be the conventional channel that risk affects the rate of savings and investment and through that growth.

Table 2 adds a measure of private credit and its interaction with volatility. In accordance with our theoretical resutls, the interaction term is positive and statistically significant. What is more, the coefficient of volatility is now more stable across specifications, suggesting that the missing variable for private credit was probably the reason for the instability of the coefficient of volatility in the Ramey-Ramey results. Finally, the impact of volatility on growth is again unaffected by the inclusion of investment as a control.

Tables 3, 4, and 5 carry on a series of sensitivity checks. In Table 4, we use different measures of human capital. In Table 5, we use different measures of financial development. In Table 6, we consider averages over the 1960-1995 period rather than initial values in 1960. Our results are robust.

Investment???

R&D Share???

5.2 Sensitivity of Growth and Shocks

We next use the time-series variation in growth and shocks together with the cross-country variation in private credit.

Table ? reports the effect of private credit on the sensitivity of growth to terms-of-trade shocks. The interaction term is strongly negative, suggesting that the same shock has a strogner impact on growth the tigher the credit constraints.

Table ? uses 5-year averages. Table ? repeats the same exercise using annual data and including lagged values of the terms-of-trade shock. Table ? then replaces the terms-of-trade shock with “exogenous shock”. The latter is defined as .... The results again indicate that tigher credit constraints result to a higher sensitivity of growth on shocks. Note also that shocks appear to have an effect on growth with a lag of one or two years, which is consistent with the idea that shocks affect the composition of contemporaneous investment, which in turn affects growth with some lag.

5.3 Cyclicality in R&D and Investment

6 Concluding Remarks...................

EMPIRICAL IMPLICATIONS

- low credit $\Rightarrow$ low R&D, low growth, and high volatility
- low credit $\Rightarrow$ strong impact of volatility on growth
- low credit $\Rightarrow$ high sensitivity of growth to shocks (especially lagged)
- low credit $\Rightarrow$ less procyclical (or more countercyclical) R&D

EMPIRICAL FINDINGS

Growth and Volatility

Investment, R&D, and Volatility

[Tables 1–6]

Table 2a. Growth, volatility and credit constraints

Dependent variable: Growth 1960-1995

	Whole sample				OECD countries			
Independent variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
initial income		-0.0071	-0.0139	-0.0169		-0.0177	-0.0230	-0.0251
		(-2.56)**	(-4.50)***	(-5.48)***		(-6.69)***	(-9.29)***	(-8.06)***
volatility	-0.2465	-0.4129	-0.3518	-0.5936	0.2712	-0.5165	-0.4279	-0.5800
	(-2.60)***	(-3.06)***	(-2.86)***	(-3.84)***	(1.41)	(-1.73)*	(-1.88)*	(-1.69)
private credit		-0.00005	-0.00007	-0.00013		-0.00019	-0.00005	-0.00010
		(-0.29)	(-0.45)	(-0.87)		(-1.26)	(-0.45)	(-0.82)
*volatility*private credit*		0.0113	0.0086	0.0107		0.0080	0.0038	0.0055
		(2.59)**	(2.11)**	(2.56)**		(1.67)^	(1.04)	(1.24)
pop growth			-0.0071	-0.0084			0.0019	0.0011
			(-2.75)***	(-3.26)***			(0.94)	(0.50)
sec school enrollment			0.0209	0.0116			0.0098	0.0065
			(1.63)^	(0.93)			(2.42)**	(1.54)
government size				0.0001				0.0001
				(0.41)				(0.35)
inflation				0.0002				-0.0004
				(1.88)*				(-0.66)
black market premium				-0.0122				-0.0147
				(-1.44)				(-0.18)
trade openness				0.00011				-0.00002
				(1.90)*				(-0.45)
F-test (volatility terms)		0.0103	0.0213	0.0014		0.2462	0.0963	0.2507
F-test (credit terms)		0.0001	0.0076	0.0028		0.0690	0.0256	0.2282
R-squared	0.0904	0.3141	0.4646	0.6383	0.0829	0.7894	0.9050	0.9513
N	70	70	69	62	24	22	21	20

Table 2b. Growth, volatility and credit constraints

(controlling for investment)

Independent variable	Whole sample (1)	Whole sample (2)	OECD countries (3)	OECD countries (4)
initial income	-0.0103	-0.0164	-0.0173	-0.0248
	(-4.10)***	(-5.73)***	(-6.55)***	(-7.60)***
volatility	-0.3012	-0.4738	-0.5446	-0.6265
	(-2.52)**	(-3.20)***	(-1.83)*	(-1.73)
private credit	-0.00008	-0.00014	-0.00021	-0.00012
	(-0.60)	(-1.03)	(-1.39)	(-0.91)
*volatility*private credit*	0.0069	0.0076	0.0083	0.0062
	(1.76)*	(1.91)*	(1.73)^	(1.31)
investment/GDP	0.1420	0.0905	0.0270	0.0121
	(4.68)***	(3.09)***	(1.13)	(0.62)
pop growth		-0.0077		0.0015
		(-3.20)***		(0.65)
sec school enrollment		0.0050		0.0068
		(0.43)		(1.54)
government size		0.0000		0.0001
		(0.00)		(0.49)
inflation		0.0001		-0.0002
		(1.21)		(-0.31)
black market premium		-0.0130		-0.0156
		(-1.65)^		(-0.18)
trade openness		0.00009		-0.00001
		(1.73)*		(-0.24)
F-test (volatility terms)	0.0489	0.0069	0.2157	0.2533
F-test (credit terms)	0.0814	0.1151	0.1125	0.2261
R-squared	0.4889	0.6962	0.8049	0.9536
N	70	62	22	20

Table 3. Investment and R&D response to volatility and credit constraints

	investment/GDP				R&D/investment			
Independent variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
initial income	0.0433	0.0025	0.0224	-0.0057	0.4709	-0.2344	0.4077	0.5097
	(4.52)***	(0.17)	(2.28)**	(-0.42)	(1.60)	(-0.39)	(1.69)	(0.63)
volatility	-0.5553	-0.5318	-0.7868	-1.3243	-5.6296	-12.2382	-27.9170	-32.0181
	(-1.46)	(-1.07)	(-1.64)^	(-1.94)*	(-0.53)	(-0.68)	(-0.92)	(-0.71)
private credit			0.00026	0.00015			-0.00645	-0.00852
			(0.47)	(0.22)			(-0.58)	(-0.53)
*volatility*private credit*			0.0309	0.0342			0.3553	0.5173
			(1.99)*	(1.85)*			(0.92)	(0.72)
pop growth		-0.0150		-0.0081		-0.2400		-0.2581
		(-1.20)		(-0.71)		(-1.16)		(-1.00)
sec school enrollment		0.1095		0.0731		0.3412		0.1417
		(1.80)*		(1.32)		(0.45)		(0.15)
government size		0.0014		0.0016		0.0295		0.0071
		(0.80)		(1.01)		(1.01)		(0.17)
inflation		0.0004		0.0009		-0.0930		0.0170
		(0.69)		(1.80)*		(-1.18)		(0.14)
black market premium		-0.0209		0.0083		7.2116		-4.2311
		(-0.52)		(0.22)		(0.38)		(-0.15)
trade openness		0.00014		0.00018		-0.00469		0.00114
		(0.52)		(0.73)		(-1.20)		(0.16)
R-squared	0.3471	0.4355	0.5100	0.5683	0.2310	0.5936	0.4049	0.6463
N	70	62	70	62	15	15	15	15

EMPIRICAL FINDINGS

Sensitivity of Growth to Shocks

[Tables 7-8]

Table 7. Growth, terms of trade shocks and credit constraints

5-year period averages

Independent variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
initial income		-0.0534		-0.0577	-0.0757
		(-10.38)***		(-8.25)***	(-8.06)***
terms of trade shock	0.0392	0.0324	0.1346	0.1377	0.1383
	(1.64)^	(1.53)	(3.06)***	(3.53)***	(3.60)***
private credit			-0.0661	0.0120	0.0177
			(-4.72)***	(0.77)	(1.09)
*terms of trade shock**			-0.4166	-0.4053	-0.3509
**private credit*			(-2.35)**	(-2.58)***	(-2.24)**
pop growth					-0.0359
					(-0.12)
sec school enrollment					0.0360
					(2.16)**
R-squared (between)	0.0017	0.1207	0.1078	0.0636	0.0419
N	496	494	329	328	323

Note:Panel data estimation with country fixed effects. Dependent variable is average growth over 5-year intervals in the 1960-1985 period. Terms of trade shock is defined as the growth of export prices less the growth of import prices. t-statistics in parenthesis. Constant term not shown.
****,**,*,^ significant at the 1%, 5%, 10% and 11% respectively.*

Table 8a. Terms of trade and price commodity shocks:

annual panel data with no lagged growth rates as controls

	Terms of trade shock			Price commodity shock		
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)
shock $_t$	-0.0378			0.0390		
	(-2.50)**			(1.87)*		
shock $_{t-1}$	0.0464	0.0475		0.0610	0.0596	
	(3.14)***	(3.22)***		(2.84)***	(2.77)***	
shock $_{t-2}$	0.0409	0.0493		0.0664	0.0636	
	(2.74)***	(3.39)***		(3.04)***	(2.92)***	
shock $_{lma}$			-0.0270			-0.0769
			(-0.62)			(-1.42)
priv credit $_{1960}$ **shock* $_t$	0.1935			-0.1291		
	(2.49)**			(-1.14)		
priv credit $_{1960}$ **shock* $_{t-1}$	0.0104	0.0153		-0.2314	-0.2281	
	(0.14)	(0.20)		(-1.97)**	(-1.94)*	
priv credit $_{1960}$ **shock* $_{t-2}$	-0.1461	-0.1876		-0.2446	-0.2341	
	(-1.90)*	(-2.49)**		(-2.05)**	(-1.97)**	
priv credit $_{1960}$ **shock* $_{lma}$			0.0083			0.1826
			(0.04)			(0.65)
R-squared within	0.0451	0.0419	0.0259	0.0403	0.0376	0.0166
R-squared between	0.0735	0.0728	0.0139	0.0298	0.0286	0.0064
# countries (groups)	46	46	46	44	44	44
N	2115	2115	1748	1653	1653	1314

*Note: Annual 1960-2000 data, except where lost due to lags. Dependent variable is annual growth. Shock refers to terms of trade shock or price commodity shock, as defined in the text. shock$_t$, shock$_{t-1}$, shock$_{t-2}$, shock$_{lma}$ refer to the contemporaneous, 1-year lag, 2-year lag, and (t-10, t-6) year average. Private credit in 1960 used throughout. Panel data estimation with country fixed effects. All regressions include a constant term and a linear trend. t-statistics in parenthesis. ***,**,*,^ significant at the 1%, 5%, 10% and 11% respectively.*

Table 8b. Terms of trade and price commodity shocks:

annual panel data with lagged growth rates as controls

Independent variable	Terms of trade shock (1)	(2)	(3)	Price commodity shock (4)	(5)	(6)
shock $_t$	-0.0395			0.0220		
	(-2.69)***			(1.08)		
shock $_{t-1}$	0.0571	0.0582		0.0535	0.0526	
	(3.96)***	(4.05)***		(2.57)***	(2.53)**	
shock $_{t-2}$	0.0314	0.0403		0.0546	0.0529	
	(2.15)**	(2.83)***		(2.58)***	(2.51)**	
shock $_{lma}$			-0.0226			-0.0207
			(-0.53)			(-0.40)
priv credit $_{1960}$ **shock* $_t$	0.1990			-0.0664		
	(2.63)***			(-0.60)		
priv credit $_{1960}$ **shock* $_{t-1}$	-0.0499	-0.0450		-0.1988	-0.1962	
	(-0.67)	(-0.60)		(-1.75)*	(-1.73)*	
priv credit $_{1960}$ **shock* $_{t-2}$	-0.1561	-0.1992		-0.1912	-0.1849	
	(-2.07)**	(-2.70)***		(-1.66)*	(-1.61)^	
priv credit $_{1960}$ **shock* $_{lma}$			-0.0116			0.0137
			(-0.06)			-0.05
R-squared within	0.0957	0.0922	0.0900	0.1045	0.1035	0.102
R-squared between	0.0337	0.0338	0.0010	0.0077	0.0071	0.0002
# countries (groups)	46	46	46	44	44	44
N	2115	2115	1748	1649	1649	1312

Note: Annual 1960-2000 data, except where lost due to lags. Dependent variable is annual growth. Shock refers to terms of trade shock or price commodity shock, as defined in the text. $shock_t$, $shock_{t-1}$, $shock_{t-2}$, $shock_{lma}$ *refer to the contemporaneous, 1-year lag, 2-year lag, and (t-10, t-6) year average. Private credit in 1960 used throughout. Panel data estimation with country fixed effects. All regressions include a constant term and a linear trend, and control for initial income and lagged growth (both 1- and 2-year lags). t-statistics in parenthesis.*
****,**,*,^ significant at the 1%, 5%, 10% and 11% respectively.*

Sensitivity of Investment and R&D to Shocks

[Table 9]

Table 9a. R&D as a share of investment

response to lagged growth and lagged price commodity shocks

X	lagged growth			lagged price commodity shocks			
	priv credit$_{t-5,t-1}$		priv credit$_{t-10,t-6}$	priv credit$_{t-5,t-1}$			priv credit$_{t-10,t-6}$
Independent variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
X_{t-1}	-0.2120	-0.4712	-0.6334	-0.3659	0.1422		0.1351
	(-0.27)	(-0.76)	(-0.83)	(-0.79)	(0.37)		(0.39)
X_{t-2}	-0.3871	-0.0004	-0.5901	0.2419	0.7297		0.8165
	(-0.51)	(-0.00)	(-0.78)	-0.52	(1.92)*		(2.21)**
$X_{t-10,t-6}$						0.0606	
						(0.10)	
priv credit $_{ma}$	.3565	-.0715	0.4326	0.3485	-0.0578	-0.0596	-0.0716
	(7.88)***	(-1.48)	(7.51)***	(8.74)***	(-1.28)	(-1.30)	(-1.34)
priv credit $_{ma}$ $*X_{t-1}$	0.1395	0.4638	0.7797	-0.0220	-0.2092		-0.2505
	-0.1200	-0.5200	-0.6000	(-0.03)	(-0.36)		(-0.45)
priv credit $_{ma}$ $*X_{t-2}$	-0.2436	-0.7689	-0.4668	-0.9953	-1.2277		-1.4922
	(-0.23)	(-0.90)	(-0.37)	(-1.38)	(-2.09)**		(-2.42)**
priv credit $_{ma}$ $*X_{t-10,t-6}$						0.2219	
						(0.24)	
linear trend	no	yes	no	no	yes	yes	yes
F-test (interaction terms)	0.9725	0.6467	0.8184	0.3430	0.0641	0.8110	0.0310
R-squared within	0.2278	0.5026	0.2422	0.2467	0.5047	0.4966	0.5074
R-squared between	0.1059	0.1270	0.0381	0.1408	0.2270	0.2187	0.2205
# countries (groups)	15	15	15	14	14	14	14
N	354	354	348	338	338	338	332

Note: Annual 1960-2000 data, except where lost due to lags. Dependent variable is R&D as a share of investment. X refers to lagged growth or lagged terms of trade shock. X_{t-1}, X_{t-2}, $X_{t-10,t-6}$ refer to 1-year lags, 2-year lags, and (t-10, t-6) year averages. Priv credit$_{ma}$ is a lagged moving average, either of years (t-5, t-1) or (t-10, t-6) as specified in the column heading. Panel data estimation with country fixed effects. Constant term not reported. t-statistics in parenthesis.

****,**,*,^ significant at the 1%, 5%, 10% and 11% respectively.*

Table 9b. Investment as a share of GDP

response to lagged growth and lagged price commodity shocks

X	lagged growth			lagged price commodity shocks		
	priv credit$_{t-5,t-1}$		priv credit$_{t-10,t-6}$	priv credit$_{t-5,t-1}$		priv credit$_{t-10,t-6}$
Independent variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
X_{t-1}	43.9146	48.7462	46.8449	17.4819	9.3795	12.2188
	(2.20)**	(2.67)***	(2.35)**	(1.43)	(0.81)	(1.17)
X_{t-2}	40.9369	34.0876	48.3666	0.8079	-6.7021	-12.8768
	(2.10)**	(1.92)*	(2.44)**	-0.07	(-0.58)	(-1.17)
priv credit $_{ma}$	-3.3926	4.3228	-3.2607	-4.5381	1.8440	5.7449
	(-2.90)***	(3.05)***	(-2.17)**	(-4.34)***	(1.34)	(3.60)***
priv credit $_{ma}$ $*X_{t-1}$	-40.9659	-46.8908	-54.2711	-4.4502	-1.3756	-4.5806
	(-1.42)	(-1.78)*	(-1.61)^	(-0.23)	(-0.08)	(-0.28)
priv credit $_{ma}$ $*X_{t-2}$	-5.0000	4.3891	-10.1747	20.6600	24.2388	37.1052
	(-0.18)	(0.17)	(-0.31)	(1.09)	(1.36)	(2.03)**
priv credit $_{ma}$ $*X_{t-10,t-6}$						
linear trend	no	yes	no	no	yes	yes
F-test (interaction terms)	0.3027	0.1943	0.1978	0.5475	0.3690	0.1266
R-squared within	0.1626	0.3046	0.1584	0.1470	0.2497	0.2772
R-squared between	0.0236	0.1407	0.0257	0.0443	0.0468	0.0636
# countries (groups)	15	15	15	14	14	14
N	353	353	347	337	337	331

Note: Annual 1960-2000 data, except where lost due to lags. Dependent variable is investment as a share of GDP. X refers to lagged growth or lagged terms of trade shock. X_{t-1}, X_{t-2}, $X_{t-10,t-6}$ refer to 1-year lags, 2-year lags, and (t-10, t-6) year averages. Priv credit $_{ma}$ is a lagged moving average, either of years (t-5, t-1) or (t-10, t-6) as specified in the column heading. Panel data estimation with country fixed effects. Constant term not reported. t-statistics in parenthesis.

****,**,*,^ significant at the 1%, 5%, 10% and 11% respectively.*

EMPIRICAL FINDINGS

Cyclical Behavior of Investment and R&D

[Tables 10-11]

Table 10. Effect of Private Credit on Cyclicality of R&D

Correlation between cyclical components of R&D and GDP

	Cross country				Longitudinal	
	(1)	(2)	(3)	(4)	(5)	(6)
Private credit:	no controls	initial GDP + investment	(2) + human capital	(3) + institutional controls	fixed effects	random effects
	Panel A: current correlation					
Lagged	0.271	0.076	-0.616	-0.263	**-0.557**	**-0.418**
	(0.289)	(0.280)	(0.487)	(0.4764)	**(0.159)*****	**(0.145)*****
Beginning period	0.173	0.052	-0.564	-0.160	**-0.494**	**-0.413**
	(0.285)	(0.267)	(0.452)	(0.464)	**(0.119)*****	**(0.113)*****
Average	0.402	0.270	-0.382	0.013	**-0.342**	**-0.284**
	(0.320)	(0.305)	(0.436)	(0.625)	**(0.110)*****	**(0.103)*****
	Panel B: correlation between current R&D and 1 year lagged GDP					
Lagged	0.223	0.206	**-1.173**	-0.734	**-1.255**	**-1.043**
	(0.336)	(.388)	**(0.461)****	(0.578)	**(0.156)*****	**(0.146)*****
Beginning period	0.165	0.173	**-1.107**	-0.708	**-0.855**	**-0.753**
	(0.328)	(0.371)	**(0.416)****	(0.541)	**(0.121)*****	**(0.116)*****
Average	0.207	0.179	**-0.951**	-0.743	**-0.849**	**-0.722**
	(0.338)	(0.363)	**(0.259)*****	(0.405)	**(0.113)*****	**(0.105)*****
	Panel C: correlation between current R&D and 2 year lagged GDP					
Lagged	0.050	0.241	-0.558	-0.730	**-1.392**	**-0.988**
	(0.362)	(0.396)	(0.726)	(1.169)	**(0.191)*****	**(0.162)*****
Beginning period	0.048	0.21706	-0.544	-0.793	**-0.923**	**-0.742**
	(0.350)	(0.378)	(0.667)	(1.083)	**(0.149)*****	**(0.133)*****
Average	0.068	0.168	-0.596	-1.103	**-1.075**	**-0.853**
	(0.327)	(0.3406)	(0.442)	(0.761)	**(0.131)*****	**(0.116)*****

Table 11. Effect of Private Credit on Cyclicality of Investment

Correlation between cyclical components of investment rate and GDP

	Cross country				Longitudinal	
	(1)	(2)	(3)	(4)	(5)	(6)
Private credit:	no controls	initial GDP + investment	(2) + human capital	(3) + institutional controls	fixed effects	random effects
			Panel A: current correlation			
Lagged	-0.116	-0.137	-0.242	-0.267	**0.513**	**0.458**
	(0.128)	(0.127)	(0.217)	(0.314)	**(0.053)***	**(0.050)***
Beginning period	-0.080	-0.124	-0.213	-0.267	**0.458**	**0.416**
	(0.126)	(0.121)	(0.202)	(0.293)	**(0.045)***	**(0.043)***
Average	-0.176	-0.168	-0.095	-0.075	**0.4313**	**0.389**
	(0.106)	(0.096)^	(0.152)	(0.262)	**(0.035)***	**(0.034)***
			Panel B: correlation between current investment rate and 1 year lagged GDP			
Lagged	0.011	0.009	**0.434**	0.328	**0.707**	**0.649**
	(0.197)	(0.222)	**(0.208)***	(0.288)	**(0.082)***	**(0.077)***
Beginning period	-0.006	0.018	**0.426**	0.367	**0.608**	**0.566**
	(0.190)	(0.211)	**(0.182)***	(0.248)	**(0.070)***	**(0.067)***
Average	-0.007	-0.030	**0.442**	**0.481**	**0.650**	**0.613**
	(0.171)	(0.184)	**(0.066)***	**(0.109)***	**(0.052)***	**(0.050)***
			Panel C: correlation between current investment rate and 2 year lagged GDP			
Lagged	0.121	0.098	**0.813**	**0.992**	**0.520**	**0.458**
	(0.215)	(0.226)	**(0.237)***	**(0.213)***	**(0.097)***	**(0.088)***
Beginning period	0.084	0.105	**0.747**	**0.961**	**0.459**	**0.414**
	(0.210)	(0.214)	**(0.222)***	**(0.163)***	**(0.081)***	**(0.075)***
Average	0.047	-0.004	0.419	0.603	**0.622**	**0.576**
	(0.204)	(0.197)	(0.228)^	(0.355)	**(0.060)***	**(0.057)***