# Volatility and Growth

## Financial Development and Cyclical Composition of Investment*


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**Abstract**

This paper investigates how financial development affects the cyclical behavior of the composition of investment and thereby volatility and growth. We first develop a simple endogenous-growth model in which firms engage in two types of investment: a short-term investment activity and a long-term productivity-enhancing one. Because it takes longer time to complete, long-term investment has a relatively less procyclical return but also a higher probability to be hit by a liquidity shock. Under complete financial markets, only the opportunity-cost effect is present: long-term investment is countercyclical, thus mitigating volatility. But when firms face tight borrowing constraints, the liquidity effect dominates: long-term investment turns procyclical, thus amplifying volatility. We next confront the model with a panel of countries over the period 1960-2000. In accordance with the predictions of the model, we find that a lower degree of financial development has no significant effect on the sensitivity of total investment to exogenous shocks, but predicts a higher sensitivity of both the composition of investment and productivity growth to lagged shocks.



*JEL codes:*

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# 1 Introduction

This paper is motivated by three observations: the negative correlation between growth and volatility in the cross-section of countries; the failure of investment/saving rates to account for this negative correlation; and the fact that this correlation is stronger the lower the level of financial development. In the light of these facts, we propose that a key missing element is the *composition* of investment: how it varies over the business cycle; how it depends on financial development; and how it affects growth and volatility.

**Motivating facts.** The idea that there is a close connection between productivity growth and the business cycle goes back at least to Schumpeter, Hicks, and Kaldor in the 1940s-1950s. Using cross-sectional data from 92 countries, Ramey and Ramey (1995) find a negative correlation between volatility and growth (the former measured by the standard deviation of annual per-capita GDP growth rates and the latter by the corresponding mean). As shown in columns (1)-(4) of Table 1, which repeat their exercise in an expanded cross-country data set that we use in this paper, this relation is robust to controlling for policy and demographics variables as in Levine et al. (2000).

To the extent that this evidence reflects a causal effect of volatility on growth,[1] a straightforward candidate explanation is risk aversion: higher volatility means more investment risk, which tends to discourage investment and slow down growth. This effect may be partly or totally offset by the precautionary motive for savings: higher income risk may raise precautionary savings, reduce interest rates, and thereby boost investment. In an AK economy, for example, the general-equilibrium effect of volatility on savings and growth is negative if and only if the elasticity of intertemporal substitution is higher than one (Jones, Manuelli and Stacchetti, 2000).[2] In any event, the simple neoclassical paradigm *can* account for a negative correlation between volatility and growth to the extent that higher volatility is correlated with lower investment rates.

As shown in columns (4)-(8) of Table 1, however, controlling for investment rates does not subsume the impact of volatility. In the whole sample, for example, the change in the coefficient of volatility is insignificant, with the point estimate falling from $-0.26$ to $-0.22$. Prima facia, this finding suggests that the main channel through which volatility affects growth is not the rate of investment.

[insert Table 1 here]

In Table 2, we repeat the growth regressions of Table 1 now including the level of financial development and its interaction with volatility.[3] The level effect is no surprise: financial develop-

[1] The effect remains negative when Ramey and Ramey (1995) instrument volatility with (arguably) exogenous innovations in government spending. See also Gavin and Hausmann (1996).

[2] The results in Angeletos (2004) suggest that in a neoclassical growth economy – where the income share of capital is less than one – productivity risk can have a negative impact on saving rates even when the elasticity of intertemporal substitution is substantially below one.

[3] Financial development is measured by the ratio of private credit to GDP; see Section 5.

ment is positively correlated with growth. The news is the strong interaction effect: the negative correlation between volatility and growth appears to be stronger in countries with lower financial development.[4] This interaction effect is robust to controlling for policy and demographics variables, as well as for the rate of investment rate.

[insert Table 2 here]

**Model and theoretical results.** Motivated by these facts, the first part of the paper develops a simple endogenous-growth model which focuses on the cyclical composition of investment as the main propagation channel. A large number of agents ("entrepreneurs") engage in two types of investment activity. The one type, which we call "short-term investment", takes relatively little time to build and generates output relatively fast. The other, which we call "long-term investment", takes more time to complete and yields a return further in the future, but contributes relatively more to productivity growth.

That borrowing constraints may amplify the cyclical variation in the demand for investment is of course well known. Note, however, that this effect may be offset in general equilibrium by the endogenous adjustment of interest rates: if the supply of savings is inelastic, the amplification shows up in interest rates, not in investment or growth rates.[5] This paper instead focuses on how credit constraints affect the propagation of shocks through the composition of investment.

In particular, we assume that the supply of savings is inelastic over the business cycle, thus completely shutting down the standard credit channel. We also assume that borrowing capacity is independent of the type of investment (equivalently, funds borrowed for one type of investment could be used for the other), which precludes any ad hoc effect on the composition of investment. We thus isolate a novel horizon effect: because it takes longer to complete, the long-term investment is also more likely to be interrupted by a liquidity shock.

This effect is of course absent under perfect credit markets. The cyclical composition of investment is then dictated merely by an opportunity-cost effect: to the extent that there is mean-reversion in exogenous productivity, so that short-term returns are more procyclical than long-term returns, the opportunity cost of long-term investment is lower in recessions than in booms.[6] Hence, with complete markets, the fraction of savings allocated to long-term investment is countercyclical.

This cyclicality of relation is reversed once firms face sufficiently tight borrowing constraints. This is not because borrowing constraints limit the *ability* to invest – in our model, the interest rate adjust in general equilibrium so that neither type of investment is constrained ex ante. It is rather because tighter constraints imply a higher probability that the firm will fail to meet a liquidity

[4] In column (1), for example, a one standard deviation increase in the level of financial development would reduces the impact of a 1% rise in volatility by $-0.32\%$ ($= 0.011 \cdot 29$).

[5] Moreover, our empirical findings in Section 5 do not support amplification in the rate of investment.

[6] An opportunity-cost effect of this kind has been emphasized by Aghion and Saint-Paul (1998) and more recently by Barlevy (2004).

shock ex post, thus foregoing part of the return to then sunk long-term investment. This in turn reduces ex ante the *willingness* to undertake a long-term investment.

In particular, to the extent that the entrepreneurs' borrowing capacity increases with current cash-flow, long-term investments face a higher liquidity risk during recessions, where cash-flow is lower. When borrowing constraints are sufficiently tight, this effect dominates the opportunity-cost effect discussed above, implying that long-term investment becomes procyclical.

The procyclicality of long-term investment in turn generates procyclicality in the endogenous component of aggregate productivity. Thus, in contrast to the mitigating effect under complete markets, the cyclical behavior of the composition of investment introduces a novel amplification mechanism.

Finally, tighter the borrowing constraints tend to predict a more negative relation between volatility and growth. This can be due to a simple spurious effect: a lower level of financial development implies both lower mean growth and higher volatility – the former because the higher liquidity risk reduces the level of long-term investment in every state of the world, the latter because of the amplification effect discussed above. But it can also be due to a causal effect: in some cases, more volatility increases the average level of liquidity risk, thus leading to a reduction in long-term investment and productivity growth.

**Empirical findings.** Since the volatility of GDP growth is endogenous, a causal interpretation of the correlations described earlier is impossible. In the second part of the paper, we thus test the model using terms of trade and export- or import-weighted indices of commodity prices as our measures of exogenous shocks in the economy.

We first examine the response of growth to terms-of-trade or commodity-price shocks. Looking at 5-year averages in a sample of 73 countries between 1960 and 1985, we find that an adverse terms-of-trade or commodity-price shock has a smaller negative impact on growth in countries with higher financial development, the latter measured again by the ratio of private credit to GDP.

The same picture emerges when we consider an annual panel with country fixed effects. The interaction between private credit and one- or two-year lagged shock is significant both statistically and economically. Moreover, financial development appears not to subsume the role of other policies or institutions: the interaction between shocks and private credit remains significant once we control for intellectual property rights, government expenditures, inflation, and the black-market premium. Finally, the interaction between shocks and private credit looses significance but remains negative even when we add year fixed effects

We next look at the response of the rate and the composition of investment to shocks. For that purpose, we proxy the fraction of long-term productivity-enhancing investments by the ratio of R&D to total investment. Data availability limits the analysis to an annual panel of 14 OECD countries over the period 1973-1997 and reduces the statistical significance of some results. Nevertheless, we find that the fraction of investment allocated to R&D is more sensitive to shocks the lower the level of financial development. On the other hand, total investment as a share of GDP does not respond much to commodity price shocks. These results appear to reject the hypothesis of amplification in the overall rate of investment and instead favor a composition effect as a potentially important propagation channel.

**Related literature.** King and Rebelo (1993), Stadler (1990), and Jones, Manuelli and Stacchetti (2000) analyze the relation between volatility and growth within the $AK$ class of models, but do not consider either the cyclical behavior of the allocation of investment or the role of financial development. Hall (1991), Gali and Hammour (1991), Aghion and Saint-Paul (1998), and Barlevy (2004) examine the cross-sectoral allocation of investment, but also assume perfect capital markets.[7]

The role of financial constraints and liquidity risk, on the other hand, have been the subject of a large literature, including Bernanke and Gertler (1989), Banerjee and Newman (1991), King and Levine (1993), Obstfeld (1994), Kiyotaki and Moore (1997), Holmstrom and Tirole (1998), Aghion, Banerjee and Piketty (1999).[8] We depart from this earlier work by focusing on how credit constraints interact with the horizon of investment and how this affects the *cyclical* composition of investment. Angeletos (2004) also considers how investment risks may affect the cyclical allocation of investment, but focuses on private versus public equity.

Related is also Caballero and Hammour (1994), who though focus on the role of adjustment costs and the cleansing effect of recessions. Acemoglu and Zilibotti (1997), on the other hand, show how lower levels of income, by constraining the ability to diversify sector-specific risks, may lead to both higher volatility and lower growth.[9] This paper instead focuses on the interaction of credit constraints and the composition of investment.

The rest of the paper is organized as follows. Section 2 outlays the model. Section 3 analyzes the composition of investment and Section 4 the implications for growth and volatility. Section 5 contains the empirical analysis. Section 6 concludes.

## 2 The model

In any given period $t$, the economy is populated by a continuum of mass 1 of overlapping generations of two-period lived agents ("entrepreneurs"), who are indexed by $i$ and uniformly distributed over $[0, 1]$. In the first period of her life, an entrepreneur receives an exogenous endowment of wealth and decides how much to invest in short-term versus long-term investment. Short-term investment produces at the end of the first period, whereas long-term investment produces at the end of the second period. In between, a random liquidity is realized, which threatens to reduce the return

[7] Francois and Lloyd-Ellis (2003), on the other hand, consider a Schumpeterian growth model in which cycles are generated by firms' incentives to synchronize their innovations, as in Shleifer (1986).

[8] See Levine (2004) for an excellent review of the literature on financial development and economic growth.

[9] See however Koren and Tenreyro (2004).

of long-term investment if it is not financed. At the end of the second period, the entrepreneur consumes her total life-time income and dies. The life-span of an entrepreneur is illustrated in Figure 1 and further explained below.

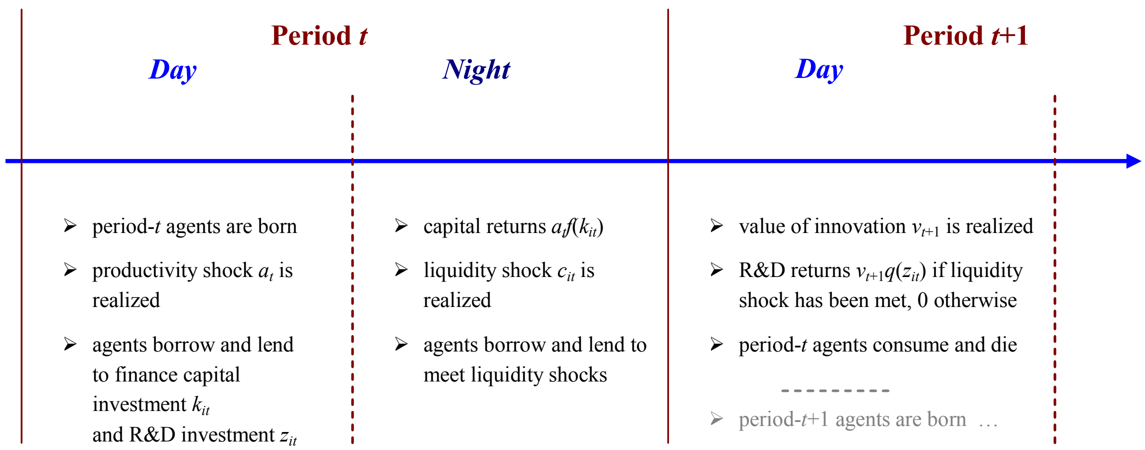


Figure 1: The life of an entrepreneur.

**Technology and productivity shocks.** Aggregate productivity has two components: an exogenous and an endogenous one. We denote the endogenous component in period $t$ with $T_t$ and call it the level of knowledge. The determination of $T_t$ will be described later. The exogenous component, on the other hand, is denoted by $a_t$ and is assumed to follow a Markov process with support $[\underline{a}, \overline{a}] \subseteq \mathbb{R}$, unconditional mean normalized to 1, and conditional mean $\mathbb{E}_{t-1} a_t = a^{\rho}_{t-1}$, where $\rho \in (0, 1)$ parametrizes the persistence in exogenous productivity.

**Initial budget constraint.** Consider an entrepreneur born in period $t$. In the beginning of life, the entrepreneur receives an endowment of wealth $W^i_t$. In the first period of her life, the entrepreneur must decide on how to allocate her initial endowment between short-run investment, $K^i_t$, long-term investment, $Z^i_t$, and savings in the riskless bond, $B^i_t$. To ensure a balanced-growth path, we assume that the initial endowment and the costs of short-term and long-term investments are proportional to $T_t$, and denote with $w^i_t = w^i_t/T_t$, $k^i_t = K^i_t/T_t$, $z^i_t = Z^i_t/T_t$, and $b^i_t = B^i_t/T_t$ the "detrended" levels of short-term investment, long-term investment, and bonds holdings. The initial budget constraint thus reduces to

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

**Short-term and long-term investment.** Short-term investment takes only one step to complete, namely the initial investment $K^i_t$ in the beginning of the first period, and generates output

$$\Pi^i_t = a_t T_t \pi(k^i_t)$$

at the end of the same period, where $\pi$ is a "neoclassical" production function (i.e., such that

$\pi' > 0 > \pi''$, $\pi'(0) = \infty$, and $\pi'(\infty) \leq 0$).

Long-term investment, on the other hand, takes two steps to complete: the initial investment $Z_t^i$ incurred in the beginning of the first period and an additional random adjustment cost $C_t^i$ incurred in the end of the first period. Long-term investment produces

$$\Pi_{t+1}^i = a_{t+1} T_t q(z_t^i) + C_t^i$$

at the end of the second period if this additional cost has been met, and nothing otherwise, where $q$ is a neoclassical production function ($q' > 0 > q''$, $q'(0) = \infty$, $q'(\infty) \leq 0$). To ensure a balanced growth path, we assume that $C_t^i$ is proportional to $T_t$ and let $c_t^i = C_t^i / T_t$ be i.i.d. across agents and periods, with support $[0, \bar{c}]$, c.d.f. $F$, and density $f$. Unless otherwise stated, we further simplify by assuming that the c.d.f. is isoelastic: $F(c) = (c/\bar{c})^{\phi}$ , where $\phi, \bar{c} > 0$.

**Remarks.** Note that the return to each type of investment depends on the contemporaneous exogenous productivity shock (i.e., $a_t$ for the short-term investment, $a_{t+1}$ for the long-term one), whereas both depend on the level of knowledge that the entrepreneur learns in the beginning of his life (i.e., $T_t$). The first assumption is essential: together with the assumption that $a_t$ is mean-reverting will ensure that the return to short-term investment is more cyclical than the return to long-term investment. The second assumption, instead, is not important: assuming that the output of long-term investment depends on $T_{t+1}$ rather than $T_t$ would not change any of the results.[10] The assumption that $\Pi_{t+1}^i$ includes $C_t^i$ is also inessential: it ensures that $C_t^i$ represents a pure *liquidity shock.* That is, since $a_{t+1} T_t q(z_t^i) > 0$, it is always optimal to pay the additional cost; whether, however, the firm will be able to do so will depend on the efficiency of credit markets.

There are many possible ways to think about what these two types investments or the liquidity shock might be. For example, the short-term investment might be putting money into your current business, while long-term productivity-enhancing investment may be starting a new business. Or, the short-term investment may be maintaining existing equipment or buying a machine of the same vintage as the ones already installed, while the long-term investment is building an additional plant, learning a new skill, or adopting a new technology. Similarly, the liquidity shock might be an extra cost necessary for the new technology to be adapted to domestic market conditions once the new technology has been adapted; or a health problem which the entrepreneur needs to overcome or otherwise he won't be alive to enjoy the fruits of his long-term investment; or some other idiosyncratic shock that is threatening to ruin his business unless he has enough liquidity to overcome it.

Finally, the fact that long-term productivity-enhancing investments – such as setting up a new business, learning a new skill, adopting a new technology, or engaging in R&D – are largely in

[10] This would introduce a complementarity in long-term investment activity which in turn would increase its counter-cyclicality under complete markets and also increase its procyclicality under sufficiently tight borrowing constraints.

intangible form explains why a large fraction of the value of such investments need not be tradeable and may be lost in case the liquidity shock is not met. The assumption that everything is lost is then only for simplicity.

**Entrepreneur's objective.** The entrepreneur is risk neutral and consumes only in the last period of her life. Hence, expected life-time utility is simply $\mathbb{E}_t[W_{t+1}^i]$, where

$$W_{t+1}^i = \Pi_t^i + \left(\Pi_{t+1}^i - C_t^i\right) \mathbb{I}_t^i + (1+r_t)B_t^i \tag{1}$$

is the entrepreneur's final-period wealth and $\mathbb{I}_t^i$ is an indicator variable such that $\mathbb{I}_t^i = 1$ if the firm succeeds in paying for the implementation of the innovation and $\mathbb{I}_t^i = 0$ otherwise. Equivalently, $W_{t+1}^i = w_{t+1}^i T_t$, where

$$w_{t+1}^i = a_t \pi(k_t^i) + a_{t+1} q(z_t^i) \mathbb{I}_t^i + (1+r_t) b_t^i \tag{2}$$

is final wealth normalized by the level of knowledge.

**Credit markets.** Credit markets open twice every period. The "day" market takes place in the beginning of the period, *before* the realization of the long-term investment adjustment cost. The "overnight" market takes place at the end of the period, *after* the realization of the adjustment cost.

On the day market, an entrepreneur born at date $t$ can borrow only up to $m \geq 0$ times her initial wealth. Thus she faces the borrowing constraint

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

where $\mu = 1 + m \geq 1$. Similarly, on the overnight market, the entrepreneur can borrow up to $\mu$ times her end-of-current-period wealth, $X_t^i = a_t T_t \pi(k_t^i) + (1+r_t)\, B_t^i$, for the purpose of covering the adjustment cost $C_t^i$. Thus,the probability that the entrepreneur will be able to meet the liquidity shock and enjoy the fruits of his long-term investment is given by

$$p_t^i \equiv \Pr\left(c_t^i \leq \mu x_t^i\right) \equiv F\left(x_t^i\right),$$

where $x_t^i \equiv X_t^i / T_t = a_t \pi(k_t^i) + (1+r_t)\, b_t^i$.

Finally, we assume that wealth cannot be stored during the day, whereas overnight storage can take place at a one-to-one rate. The first assumption implies that the "day" interest rate $r_t$ will adjust so that the excess aggregate demand for the riskless bond in the day market is zero. This is equivalent to imposing the resource constraint

$$\int_i \left[k_t^i + z_t^i\right] = w. \tag{3}$$

The second implies that the "overnight" interest rate is bounded below by 0. To ensure that the overnight interest rate equals zero in all states, it suffices to restrict the set of parameters so that

$$\bar{c} - \underline{a}\pi\left(k\left(\underline{a}\right)\right) \leq 0, \tag{4}$$

where $k(a)$ is the solution to $a\pi'(k) = a^{\rho}q'(1-k)$.

**Endogenous growth.** To complete the model, we need to describe the growth process, which here boils down to specifying the dynamics of $T_t$. Assuming that the knowledge accumulated by one generation spills over to the next generation, and identifying the knowledge produced by entrepreneur $i$ in generation $t$ with $\tilde{T}_t^i = T_t q\left(z_t^i\right)\mathbb{I}_t^i$, we let the level of technology available to the next generation be

$$T_{t+1} = \int_i \tilde{T}_t^i = \int_i T_t q(z_t^i)\mathbb{I}_t^i.$$

This is essentially the same as assuming that knowledge accumulates at a rate proportional to the level of long-term investment in the economy, like in many other endogenous-growth models (e.g., Aghion and Howitt, 1998).

# 3 Cyclical composition of investment

In this section we analyze the effect of financial development on the level and the cyclical behavior of the two types of investment. We first consider the benchmark case of complete financial markets; we then contrast it with the case of tight credit constraints.

## 3.1 Complete markets

In a complete-markets economy, entrepreneurs face no credit constraints that would prevent them from borrowing what is necessary in order to cover the adjustment costs associated with long-term investment. This implies that the long-term investment of an entrepreneur in her first period of life will always pay out next period.

Expected wealth for entrepreneur $i$ is thus

$$a_t\pi(k_t^i) + \mathbb{E}_t a_{t+1}q(z_t^i) + (1+r_t)b_t^i,$$

which the entrepreneur maximizes over $\left(k_t^i, z_t^i, b_t^i\right)$ subject to the budget constraint

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

Obviously, all entrepreneurs make identical choices and we can drop the $i$ superscripts. Since $\pi$

and $q$ are strictly concave, the following first-order conditions are both necessary and sufficient:

$$a_t \pi'(k_t) = 1 + r_t \quad \text{and} \quad \mathbb{E}_t a_{t+1} q'(z_t) = 1 + r_t.$$

It follows that the marginal rate of substitution between the two types of investment is given by

$$\frac{q'(z_t)}{\pi'(k_t)} = \frac{a_t}{\mathbb{E}_t a_{t+1}} = a_t^{1-\rho}, \tag{5}$$

which is increasing in $a_t$ as long as $\rho < 1$.

In equilibrium, the (day) interest rate $r_t$ adjusts so that the resource constraint is satisfied,

$$k_t + z_t = w, \tag{6}$$

which means that total savings are acyclic. Combining (5) and (6) implies that, in general equilibrium, an increase in $a_t$ reduces $z_t$, increases $k_t$ and increases $r_t$. We thus conclude:[11]

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

As long as there is some mean-reversion in the business cycle, profits in the immediate future (i.e., the return to short-term investment) is more sensitive to the contemporaneous state of the economy than the present value of profits anticipated further in the future (i.e., the expected value of long-term investments).[12] It follows then that $k_t$ should be more procyclical than $z_t$. In the extreme case where aggregate shocks were not persistent at all, so that $\mathbb{E}_t a_{t+1}$ would remain constant over the business cycle, the demand for long-term investment would also remain invariant over the cycle for any given interest rate. However, the interest rate would be procyclical, and therefore the demand for long-term investment, $z_t$, will be countercyclical in equilibrium. When $a_t$ is persistent, the demand for both types of investment is procyclical, but as long as $a_t$ is mean reverting, the demand for long-term investment is less procyclical than the demand for short-term investment, implying that $z_t$ remains countercyclical.

**Example 1.** Suppose that $\pi(k) = k^\alpha$ and $q(z) = z^\alpha,\ 0 < \alpha < 1$. Condition (5) then reduces to $(k_t/z_t)^{1-\alpha} = a_t^{1-\rho}$, which together with (6) implies

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

[11] The property that the *level* of long-term investment ($z_t$) is countercyclical hinges on the assumption that the aggregate supply of savings ($w$) is acyclical. If aggregate savings were procyclical, the level of long-term investment could be procyclical while the *fraction* of savings allocated to long-term investment, $z_t/(z_t + k_t)$, remains countercyclical.

[12] This is related to the opportunity-cost effect stressed by Aghion and St. Paul (1998).

where $\eta = (1-\rho)/(1-\alpha) > 0$. Hence, $z_t$ is countercyclical (i.e., decreasing in $a_t$), whereas $k_t$ is procyclical (i.e., increasing in $a_t$).

### 3.2 Incomplete markets

Credit constraints limit entrepreneurs' borrowing capacity to a finite multiple $\mu \geq 1$ of their current wealth in both periods of their lifetime. In particular, an entrepreneur born at date $t$ faces the constraint $k_t^i + z_t^i \leq \mu w$ when she makes her investment choices at the beginning of period $t$, and she succeeds in covering the liquidity shock at the end of period $t$ if and only if $c_t^i \leq \mu \left[ a_t \pi(k_t^i) + (1+r_t)\, b_t^i \right]$. It follows that the entrepreneurs investment problem is given by the following:

$$\max_{k_t^i, z_t^i, b_t^i} \{ a_t \pi(k_t^i) + \mathbb{E}_t a_{t+1} q(z_t^i) F\left( \mu \left[ a_t \pi(k_t^i) + (1+r_t) b_t^i \right] \right) + (1+r_t) b_t^i \} \tag{7}$$

$$\begin{aligned} s.t. \qquad & k_t^i + z_t^i + b_t^i \leq w \\ & k_t^i + z_t^i \leq \mu w \end{aligned}$$

where $F\left( \mu \left[ a_t \pi(k_t^i) + (1+r_t) b_t^i \right] \right)$ is simply the ex ante probability that long-term investment will pay out.

We assume that $\pi, q$, and $F$ are such that the objective in (7) is strictly concave, which ensures that the first-order conditions are both necessary and sufficient, as well as that all entrepreneurs make identical choices in equilibrium (and therefore we can once again drop the $i$ subscripts). The assumption of no storage within periods implies that the first constraint is never binding in equilibrium: by the resource constraint (3), $k_t + z_t = w \leq \mu w$. The first-order conditions with respect to $k_t^i$ and $z_t^i$ can then be expressed as follows:

$$\begin{aligned} a_t \pi'(k_t) + \mathbb{E}_t a_{t+1} q(z_t) f\left( \mu x_t \right) \mu \left[ a_t \pi'(k_t) - (1+r_t) \right] &= 1 + r_t, \\ \mathbb{E}_t a_{t+1} q'(z_t) F\left( \mu x_t \right) - \mathbb{E}_t a_{t+1} q(z_t) f\left( \mu x_t \right) \mu \left( 1 + r_t \right) &= 1 + r_t, \end{aligned}$$

where $x_t = a_t \pi(k_t^i) + (1+r_t) b_t^i$. The condition for $k_t$ is obviously satisfied at

$$a_t \pi'(k_t) = 1 + r_t, \tag{8}$$

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

$$\mathbb{E}_t a_{t+1} q'(z_t) = (1+r_t) \left[ \frac{1 + \mathbb{E}_t a_{t+1} q(z_t) f\left( \mu x_t \right) \mu}{F\left( \mu x_t \right)} \right]. \tag{9}$$

Since the term in brackets is no less than 1, the demand for long-term investment is (weakly) lower than than under complete markets.

In equilibrium, the interest rate $r_t$ adjusts so that $b_t = 0$, $k_t + z_t = w$, and therefore $x_t = a_t \pi(k_t)$. Let $\bar{\mu} \equiv \bar{c}/(\bar{a}\pi(1))$ and note $\mu \leq \bar{\mu}$ suffices for $\mu x_t < \bar{c}$ for all $a_t$, in which case $F(\mu x_t) < 1$, $f(\mu x_t) > 0$, and the term in brackets in (9) is strictly greater than one. It follows:

**Proposition 2** *Suppose $\mu \leq \bar{\mu}$. For any realization $a_t$, incomplete markets lead to a lower interest rate $r_t$, a higher short-term investment $k_t$, and a lower long-term investment $z_t$ as compared to complete markets.*

Next, consider the cyclical behavior of investment. Using $F(\mu x_t) = (\mu a_t \pi(k_t)/\bar{c})^{\phi}$ along with (8), (9), and $\mathbb{E}_t a_{t+1} = a_t^{\rho}$, we infer that the equilibrium allocation of savings satisfies

$$\frac{q'(z_t)}{\pi'(k_t)} = \frac{a_t^{1-\rho-\phi}}{[\mu\pi(k_t)/\bar{c}]^{\phi}} + \phi\frac{q(z_t)}{\pi(k_t)} \tag{10}$$

Together with the resource constraint, $z_t + k_t = w$, the above implies that $z_t$ is increasing (decreasing) in $a_t$ if $1 - \rho - \phi < 0$ $(> 0)$. We conclude:

**Proposition 3** *Suppose $\mu \leq \bar{\mu}$ and $\phi > 1 - \rho$. Under incomplete markets, the share of long-term investment $z_t$ is procyclical, and the share of short-term investment $k_t$ is countercyclical.*

The intuition for this result is simple. The opportunity-cost effect, which tends to make the demand for long-term investment countercyclical, is present under complete and incomplete markets alike. When, however, $\mu \leq \bar{\mu}$, a second effect emerges: the probability that the entrepreneur will fail to meet the liquidity shock is less than one in all states and, most importantly, is higher in a recession than in a boom. This liquidity-risk effect tends to make the demand for long-term investment procyclical. The condition $\phi > 1 - \rho$ then ensures that the second effect dominates: the opportunity-cost effect is weaker the higher the persistence $\rho$ in the business cycle, whereas the liquidity-risk effect is stronger the higher the elasticity $\phi$ of the probability of meeting the liquidity shock.

Finally, note that $\mu$ controls primarily the *average level* of liquidity risk, whereas $\phi$ controls its *cyclical elasticity*. Although these two parameters are exogenous in our model, lower levels of financial development may be associated with both a higher mean level and a higher cyclicality of liquidity risk. Moreover, in our model, the cyclicality of liquidity risk is also affected by $\mu$ when $\mu > \bar{\mu}$, for then a higher $\mu$ implies a larger the region of $a_t$ for which the liquidity risk becomes zero and locally insensitive to $a_t$. For these reasons, we henceforth identify "more incomplete markets" with the combination of a lower $\mu$ and a higher $\phi$.

**Example 2.** Suppose $\pi(k) = k^{\alpha}$, $q(z) = z^{\alpha}$, $\alpha < 1$, $\bar{c} = 1$, and $1 - \rho < \phi < (1-\alpha)/\alpha$.[13] Condition (10) then reduces to

$$\psi(z_t) = \mu^{\phi} a_t^{\phi+\rho-1} \tag{11}$$

[13] The assumption $\phi < (1-\alpha)/\alpha$ suffices for the objective in (7) to be strictly concave and therefore for the first-order conditions to be sufficient.

where $\psi(z) = z^{1-\alpha}(w-z)^{-\phi\alpha}(w-(1+\phi)z)^{-1}$. Clearly, $\psi(z)$ increases with $z$, whereas $\mu^{\phi}a^{\phi+\rho-1}$ increasing with $\mu$ and $a$. (11) can thus be solved for $z_t$ as an increasing function of $\mu$ and $a_t$.

**Example 3.** Suppose again $\pi(k) = k^{\alpha}$, $q(z) = z^{\alpha}$, but now let the distribution of $c$ be log-normal; the elasticity $\phi$ is then endogenous. Figures 2.a and 2.b illustrates the impact of $\mu$ on the level $z_t$ and the cylical elasticity $\partial \ln z_t / \partial \ln a_t$ of long-term investment (both evaluated at $a_t = 1$, the mean productivity level), while Figure 2.c depicts the associated probability of meeting the liquidity shock, $\delta(a_t) = F(\mu a_t \pi(k_t))$. In this example, tighter constraints lead to a lower and more procyclical long-term investment.

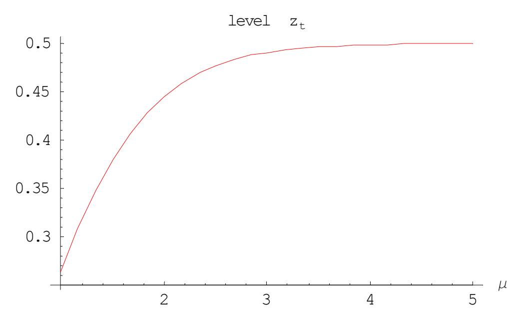


Figure 2.a: The effect of $\mu$ on the level of $z_t$.

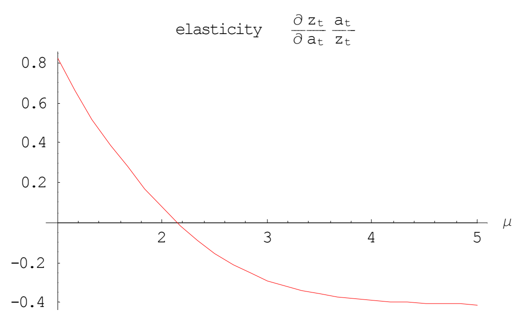


Figure 2.b: The effect of $\mu$ on the cyclical elasticity of $z_t$.

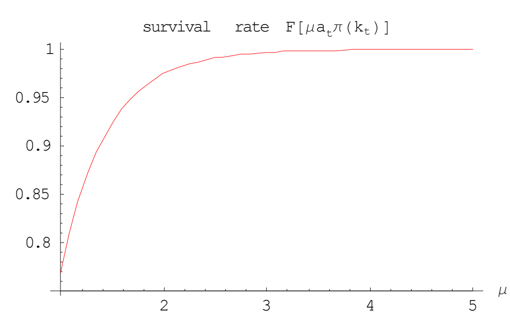


Figure 2.c: The effect of $\mu$ on liquidity risk.

# 4 Amplification, volatility and mean growth

In this section, we analyze the implications for aggregate volatility, mean growth, and the relation between the two.

## 4.1 Complete markets

Under complete financial markets, entrepreneurs can always meet the liquidity shock by borrowing whatever additional resources are necessary. Hence, letting $z^*(a_t)$ denote the complete-markets equilibrium level of long-term investment, the growth rate of technology is

$$\frac{T_{t+1}}{T_t} = \gamma^*(a_t) \equiv q(z^*(a_t)).$$

Since $z^*(a_t)$ is decreasing in $a_t$, $\gamma^*(a_t)$ is also decreasing in $a_t$.

**Proposition 4** *Under complete markets, the endogenous component of productivity growth is countercyclical and therefore mitigates the business cycle.*

Consider next the relation between volatility and growth. Whether a higher variance in $a_t$ results in higher or lower mean growth ultimately depends upon the curvatures of $q$ and $z$.

In the Cobb-Douglas case of Example 1 in Section 3.1, it is easy to check that $\gamma^*(a)$ is necessarily convex at least in a neighborhood of the mean productivity shock, implying that a small mean-preserving spread in $a_t$ starting from zero variance necessarily *increases* the mean rate of technological growth. However, $\gamma(a)$ may have both convex and concave segments and therefore the complete-markets effect of volatility on growth is ambiguous in general. Therefore, a positive relation between volatility and mean growth under complete markets may be an interesting benchmark, at least in the context of our model, but by no means is it a strong result.

## 4.2 Incomplete markets

Under sufficiently tight credit constraints ($\mu \leq \bar{\mu}$ and $\phi > 1 - \rho$), . Since only those firms that can meet their adjustment costs are able to innovate and thereby contribute to aggregate productivity growth, the growth rate of technology is now given by:

$$\frac{T_{t+1}}{T_t} = \gamma(a_t) \equiv q(z(a_t))\,\delta(a_t)$$

where $z(a_t)$ is the incomplete-markets equilibrium level of long-term investment and $\delta(a_t) \equiv F(\mu a_t \pi(w - z(a_t)))$ is the equilibrium probability of covering the liquidity shock associated with long-term investment. Clearly, $\mu \leq \bar{\mu}$ and $\phi > 1 - \rho$ suffice for $\delta(a_t) < 1$ and $z(a_t) < z^*(a_t)$ for all $a_t$, as well as for both $\delta(a_t)$ and $z_t(a_t)$ to be strictly increasing in $a_t$. It then follows that $\gamma(a_t) < \gamma^*(a_t)$ for all $a_t$, and that $\gamma(a_t)$ is strictly increasing in $a_t$.

**Proposition 5** *Under sufficiently incomplete markets (i.e., for $\mu \leq \bar{\mu}$ and $\phi > 1-\rho$), the endogenous component of productivity growth is procyclical and therefore amplifies the business cycle. Moreover, it is strictly less than that under complete markets in all states.*

Note how the amplification result contrasts with the mitigating effect of long-term investment under complete markets (Proposition 4). Whereas the opportunity-cost effect implies that long-term investment and therefore productivity growth are countercyclical under complete markets, the liquidity-risk effect contributes in making productivity growth procyclical under incomplete markets via two channels: first, by imputing procyclicality in the demand for long-term investment; and second, by making the success probability of long-term investments higher in booms than in recessions.

Next, consider the implications for the relation between volatility and growth. For any given process for the exogenous shock $a_t$, incomplete markets result to both a higher variance and a lower mean in productivity growth than complete markets. The negative cross-country relation between volatility and mean growth observed in the data may therefore reflect a *spurious* correlation imputed by cross-country differences in credit markets. Moreover, this negative relation need not diminish once one controls for the level of investment, as what matters is instead the composition of investment.

The *causal* effect of volatility on growth, on the other hand, depends again on the curvatures of $q$, $z$, and $\delta$. Like in the case of complete markets, $z$ may have both convex and concave segments. In addition, $\delta$ may also have both convex and concave segments, depending on the distribution of the liquidity shock. The effect of a mean preserving spread in $a_t$ on mean growth is thus ambiguous in general. Nevertheless, the following examples provide some insight into the conditions under which the effect may be negative.

**Example 4.** Suppose that the adjustment cost $c$ is 0 with probability $p \in (0,1)$ and $\bar{c} > 0$ with probability $1-p$. Suppose further that $z(a_t) = \hat{z} \in (0,w)$ for all $a_t$, that is, ignore the cyclicality in long-term investment. Normalizing $\pi(w-\hat{z}) = q(\hat{z}) = 1$, it follows that

$$\gamma(a_t) = \delta(a_t) = \begin{cases} 1 & \text{if } \mu a_t \geq \bar{c} \\ p & \text{if } \mu a_t < \bar{c} \end{cases}$$

Recall that the productivity shock $a_t$ has unconditional mean 1 and support $[\underline{a}, \overline{a}]$.

When $\mu \in (\bar{c}, \infty)$, firms face no liquidity risk in the absence of macroeconomic volatility (i.e., when $\underline{a} = \overline{a} = 1$) or, more generally, as long as the volatility is small enough that $\underline{a} > \bar{c}/\mu$. But, as soon as $\underline{a} < \bar{c}/\mu$, a mean-preserving spread in $a_t$ *decreases* mean growth by increasing the probability that the economy will be in a (sufficiently severe) slump where a positive fraction of firms fail to meet their liquidity shocks and complete their long-term investments.

When, instead, $\mu < \bar{c}$, only a fraction of firms succeed in completing their long-term investments in the absence of volatility or, more generally, as long as $\overline{a} < \bar{c}/\mu$. But, as soon as $\overline{a} > \bar{c}/\mu$, a mean-preserving spread in $a_t$ now *increases* mean growth by increasing the probability that the economy will enter a (sufficiently good) boom where all long-term investments are completed.

This example highlights an important reason why the (causal) effect of volatility on growth may be non-monotonic under incomplete markets. When liquidity shocks and credit constrains are severe enough that the mean probability of success is very low, higher volatility may increase mean growth by increase the chances for "resurrection". But otherwise higher volatility is likely to decrease mean growth by increasing the chances for failure.

**Example 5.** Suppose $z(a_t) = \hat{z}$ for all $a_t$, as in the previous example, but now let $c$ be uniform over $[0, \bar{c}]$. Normalizing again $\pi(w - \hat{z}) = q(\hat{z}) = 1$, we now have

$$\gamma(a_t) = \delta(a_t) = \min\{\mu a_t/\bar{c}, 1\}.$$

Whereas $\delta(a)$ was $S$-shaped (i.e., convex for low $a$, concave for high $a$) in the previous example, now it is globally concave. In other words, the resurrection effect discussed above is now absent. It follows that a sufficiently large mean-preserving spread in $a_t$ necessarily reduces mean growth; and, provided $\mu > \bar{c}$, the more so the lower $\mu$.

**Example 6.** Consider the same specification as in Example 3 of Section 3.2, assume $\ln a_t$ follows a Gaussian $AR(1)$, and let $\sigma$ denote the standard deviation of the innovations in $a_t$. Figures 3.a and 3.b illustrate how, respectively, the mean (*growth*) and the standard deviation (*vol*) of the growth rate $T_{t+1}/T_t$ vary with $\sigma$. Figure 3.c then depicts the implied relation between *growth* and *vol*. The solid lines represent complete markets ($\mu = \infty$), whereas the dashes lines correspond to incomplete markets ($\mu < \infty$). For any level of $\sigma$, incomplete markets are associated with lower growth and higher volatility than complete markets. Moreover, the relation between growth and volatility is positive under complete markets, but negative under incomplete markets. This is explained by two factors. First, the average liquidity risk is relatively small, which ensures that the resurrection effect is very weak. Second, as the liquidity risk $\delta(\alpha)$ tends to be concave in $a$, the optimal level of long-term investment $z(a)$ also tends to be concave in $a$ under sufficiently incomplete markets, whereas it is convex at least in a neighborhood of the mean productivity under complete markets; the concavity of $z(a)$ then implies that an increase in $\sigma$ tends to reduce the mean level of $z$.

The last two examples show how the model can match the third fact discussed in the introduction, that the negative correlation between volatility and growth tends to be stronger in countries with lower financial development. It should be clear, however, that in general the model makes an ambiguous prediction for the causal effect of volatility on growth and for the interaction effect of credit constraints.

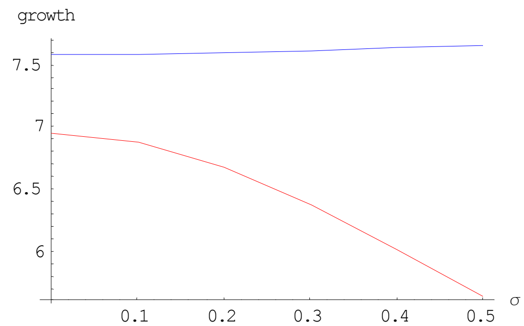


Figure 3.a: The effect of $\sigma$ on growth (blue = complete markets, red = incomplete)

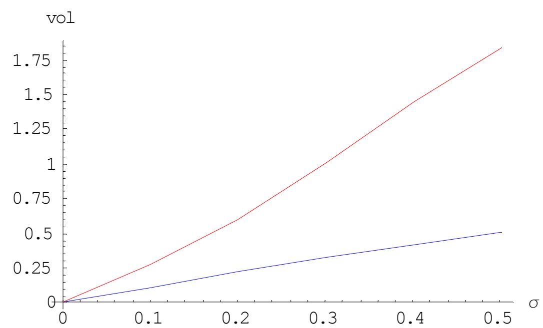


Figure 3.b: The effect of $\sigma$ on volatility (blue = complete markets, red = incomplete)

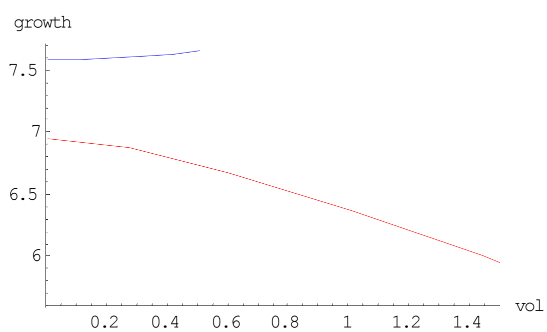


Figure 3.c: The relation between volatility and growth

# 5 Empirical analysis

Since the model allows for an ambiguous relation between volatility and growth, it can not be tested on the basis of this relation. For our empirical analysis we thus focus on the model's strongest predictions: the amplification effect and the amplification channel.

We use a panel of countries over the 1960-1995 period, which is described in detail below. We then ask two questions. Does a lower level of financial development increases the sensitivity of the growth rate to exogenous shocks? And does it do so by increasing the sensitivity of the level or the composition of investment?

## 5.1 Data

Our data is relatively standard and readily available. Annual growth is computed as the log difference of per capita income obtained from the Penn World Tables mark 6.1 (PWT). We construct a measure of aggregate volatility by taking the country-specific standard deviation of annual growth over the 1960-1995 period.

As a measure of financial intermediation we use private credit, the value of loans by financial intermediaries to the private sector divided by GDP. Data for 71 countries on 5-year interval averages between 1960 and 1995 (1960-1964, 1965-1969, etc.) was first compiled by Levine, Loyaza and Beck (2000); an annual dataset was more recently prepared and made available by Levine on his webpage. Private credit is the preferred measure of financial development by Levine et al (2000) because it excludes credit granted to the public sector and funds coming from central or development banks. We also conduct sensitivity analysis with two alternative measures of credit constraints, liquid liabilities and bank assets. The first is defined as currency plus demand and interest-bearing liabilities of banks and non-bank financial intermediaries divided by GDP; the second gives the value of all loans by banks but not other financial intermediaries.

When analyzing the response of growth to shocks we first consider terms of trade shocks, available as five-year averages between 1960 and 1985 from the Barro-Lee (1997) dataset. Changes in the terms of trade reflect export-weighted changes in export prices net of import-weighted changes in import prices, quoted in the same currency. Arguably, exchange rate fluctuations may be endogenous to the growth process and therefore regressions of growth on terms of trade shocks may be subject to reverse causality and produce biased coefficient estimates. We therefore also construct an annual index of export-weighted commodity price shocks using data on the international prices of 42 products between 1960 and 2000 available from the International Financial Statistics Database of the IMF (IFS). We first calculate the annual inflation/deflation rate for each commodity. We then average the share of that commodity in a country's exports in 1985, 1986, and 1987 as reported in the World Trade Analyzer (WTA).[14] Finally, we sum across all commodities' price changes using

[14] These were the earliest years for which complete data was available at the country-commodity level.

the corresponding export shares as weights, and obtain an annual shock index for all 70 countries between 1960 and 2000.

For the analysis on the transmission channel of credit constraints, we also need data on long term versus short-run investments. We consider R&D as a share of total investment. Unfortunately, data availability limits our sample to 14 OECD countries between 1973-1997 for which the OECD reports spending on research and development in the ANBERD database. Data on investment as a share of GDP is easily obtainable from the PWT. We also try taking alternative cuts at investments of different horizons, such as structural investment versus equipment, IT imports as a share of total imports, and the R&D embodied in capital imports as a share of total capital imports (the latter was constructed from data in Caselli and Wilson (2003)).

In the growth regressions below we follow Ramey and Ramey (1995) and Levine et al (2000) in controlling for population growth, initial secondary school enrollment, and a set of four policy variables (the share of government in GDP, inflation, the black market exchange rate premium, and openness to trade). We use demographics data from the PWT and the policy conditioning set in Levine et al (2000). When analyzing both growth and R&D we also control for property rights (*property*) and intellectual property rights (*ipr*). The former is broad measure from various editions of the Fraser Institute's Economic Freedom of the World database, while the latter is a narrower index constructed by Ginarte and Park (1997). We use the data as compiled by Caselli and Wilson (2003) for every fifth year between 1970 and 1995 for *ipr* and between 1970 and 1990 for *property*; to construct an annual panel we fill in the data by imposing a constant growth rate for each 5-year interval.

### 5.2 Sensitivity of growth to shocks

We now estimate the sensitivity of growth to exogenous shocks, exploring both the cross-section and time-series variation in the panel. We first consider the medium run, and average data over 5-year period intervals in a cross-section of over 70 countries to estimate the following specification:

$$\begin{aligned} growth_{it} &= \alpha_0 + \alpha_1 \cdot y_{it} + \alpha_2 \cdot shock_{it} + \alpha_3 \cdot credit_{it} + \\ &\quad + \gamma \cdot credit_i \cdot shock_{it} + \beta \cdot X_{it} + \mu_i + \varepsilon_{it} \end{aligned} \tag{12}$$

Here we take $growth_{it}$ and $credit_{it}$ to be the average annual growth and private credit for country $i$ in period $t$, where a period is defined as 5 consecutive non-overlapping years between 1960 and 1985. $y_{it}$ is beginning of period per capita income, and $X_{it}$ is a vector of controls. As a measure of $shock_{it}$ we consider both the average terms of trade shock and the average commodity price shock for the period. We expect a terms-of-trade improving shock to stimulate growth, and therefore $\alpha_2$ to be positive. Similarly, we anticipate a positive direct effect of financial development, thus $\alpha_3 > 0$. We are interested in the interaction term $\gamma$ and we predict $\gamma < 0$ : More credit to the private sector should make growth less sensitive to exogenous shocks or even reverse the overall effect of the shock. In the estimation we allow for country specific fixed effects.

`[insert Table 4 here]`

In Table 4 we show evidence for the expected significant positive effect of shocks on medium run growth. We also observe a strong negative coefficient on the interaction term, although it is only significant when we consider changes in the terms of trade. This result is robust to alternative measures of financial development and to using a 1-period lagged value of private credit. Because of the substantial time-series variation in private credit it is not surprising that using its initial 1960 value produces an insignificant interaction term.

We hypothesize that averaging over 5–year intervals smooths commodity price shocks relatively more than terms of trade shocks. The latter has both a price and an exchange rate component to it, and the exchange rate plausibly varies much more than prices. If so, then the potential endogeneity of growth and exchange rate fluctuations complicates the interpretation of $\alpha_2$, $\alpha_3$ and $\gamma$ in the terms of trade regressions. Moreover, our model makes predictions for the response of growth to lagged shocks, and here we consider only contemporaneous ones. We could look at the response of growth to one-period lagged shocks, but it is plausible that growth would respond to shocks sooner than with a 5-year delay. In order to analyze the effect of more recent lagged shocks, we move to an annual panel and study the impact of 1- and 2-year lagged commodity price shocks on growth today.

Table 5 reports our results from estimating the following specification in an annual panel of 44 countries between 1960 and 2000:[15]

$$\begin{aligned} growth_{it} &= \alpha_0 + \delta_0 \cdot shock_{it} + \delta_{-1} \cdot shock_{it-1} + \delta_{-2} \cdot shock_{it-2} + \\ &\quad + \gamma_0 \cdot credit_{i\_} \cdot shock_{it} + \gamma_{-1} \cdot credit_{i\_} \cdot shock_{it-1} + \gamma_{-2} \cdot credit_{i\_} \cdot shock_{it-2} + \\ &\quad + \alpha_c \cdot credit_{i\_} + \alpha_y \cdot y_{it} + \alpha_t \cdot year + \mu_i + \varepsilon_{it} \end{aligned} \tag{13}$$

Now $growth_{it}$ is annual growth, $y_{it}$ is initial per capita income, $\mu_i$ is a country fixed effect, the three $shock_{i\_}$ variables are the contemporaneous, 1-year and 2-year lagged commodity price shocks, and $credit_{i\_}$ is private credit measured in a period that varies across different specifications. In Column (1) of Table 5 we abstract from the time-series variation in financial development and estimate (13) with the initial 1960 value of private credit. We find that tighter credit constraints result in higher sensitivity to shocks, as predicted. All three shocks enter positively and very significantly, while all interaction terms receive a negative coefficient. Note that the contemporaneous interaction term is not significant; this is consistent with the idea that shocks and credit constraints affect the composition of contemporaneous investment, which in turn affects growth with a lag. Older shocks

[15] For consistency, we limit the sample to the 44 countries for which we have data on private credit in 1960 in all columns of Table 6.

have a stronger influence on growth today, but they are also dampened by the availability of credit to a larger extent. For example, a 10% beneficial shock two years ago (roughly the standard deviation of $shock_{it}$ in this sample) would translate into a direct gain of 0.007% ($= 0.0664 \cdot 0.10$) annual growth today. At this sample's mean 42% share of private credit in GDP, however, the direct effect of the shock would be overturned by the interaction term: $-0.01\%$ ($= -0.2446 \cdot 0.10 \cdot 0.42$). Thus, credit availability plays an economically significant role in the response of growth to exogenous shocks.

[insert Table 5 here]

The rest of Table 5 shows that our results persist when we account for the time-series variation in private credit. In Columns (2) and (3) we use lagged values of credit, averaged respectively over the immediately preceding five years and over the 5-year interval that ended five years ago.[16] Fixing each country's private credit at its average 1960-2000 value also produces significant coefficients of the correct sign. We have checked our results for robustness to alternative measures of financial development, as well as to including lagged growth among the controls (results not reported).[17]

[insert Table 6 here]

One concern with the results above may be that some other institutional variable that is positively associated with private credit may also interact with the commodity price shock.[18] For example, if intellectual property rights are highly positively correlated with credit availability, then long-term investment may flourish under a negative shock because of the favorable property rights protection environment and not because of financial development. If so, then omitting *ipr* from the control set may bias the coefficients on all credit terms upwards (in absolute value). Table 6 Column (1) reproduces our main result from the second column in Table 5, while Column (2) shows that it is robust to the inclusion of *ipr* and *ipr* interacted with shocks. The results persists when we include the broader measure of property rights protection in Columns (3) and (4), as well. Our results also survive the inclusion of other institutional variables and their interactions with shocks, such as the size of government and the black market premium (results not reported).

[16] The latter precludes the possibility of private credit responding to shocks since the relevant time periods for the two variables do not overlap. Note that when we use the $(t-1, t-5)$ average value of private credit, its $t-1$ value may have responded to the shock at time $t-2$. This may explain why the interaction term with $shock_{it-1}$ is not significant in Column (2) if shock really only enters linearly.

[17] When we include growth lagged 1- and 2-years, the 2-year lagged direct and interaction shock terms lose significance. A plausible explanation is that growth yesterday has had time to respond to shocks up to $t-2$ and only the $t-1$ shock remains to be passed through.

[18] Walde and Woitek (2004) find that the *level* of R&D expenditure tends to be procyclical in the G7 countries between 1973 and 2000. (See also Walde, 2004.) In contrast, we focus on the cyclical variation of R&D as a share of total investment: by construction, our model makes no useful prediction about the levels of savings, investment, and R&D.

### 5.3 Sensitivity of the level and composition of investment

The final link that remains to be established is the interaction of financial development with the cyclicality of R&D and total investment with respect to exogenous shocks. Using annual data on 14 OECD countries between 1973 and 1997 we estimate two first-stage regressions behind specification (13), namely

$$\begin{aligned} R\&D/I_{it} \quad = \quad & \alpha_0 + \delta_0 \cdot shock_{it} + \delta_{-1} \cdot shock_{it-1} + \delta_{-2} \cdot shock_{it-2} + \\ & +\gamma_0 \cdot credit_{i\_} \cdot shock_{it} + \gamma_{-1} \cdot credit_{i\_} \cdot shock_{it-1} + \gamma_{-2} \cdot credit_{i\_} \cdot shock_{it-2} + \\ & +\alpha_c \cdot credit_{i\_} + \alpha_y \cdot y_{it} + \alpha_t \cdot year + \mu_i + \varepsilon_{it} \end{aligned} \tag{14}$$

and

$$\begin{aligned} I/Y_{it} \quad = \quad & \alpha_0 + \delta_0 \cdot shock_{it} + \delta_{-1} \cdot shock_{it-1} + \delta_{-2} \cdot shock_{it-2} + \\ & +\gamma_0 \cdot credit_{i\_} \cdot shock_{it} + \gamma_{-1} \cdot credit_{i\_} \cdot shock_{it-1} + \gamma_{-2} \cdot credit_{i\_} \cdot shock_{it-2} + \\ & +\alpha_c \cdot credit_{i\_} + \alpha_y \cdot y_{it} + \alpha_t \cdot year + \mu_i + \varepsilon_{it} \end{aligned} \tag{15}$$

Now the dependent variables of interest are R&D as a share of total investment ($R\&D/I_{it}$) and investment as a fraction of GDP ($I/Y_{it}$) for country $i$ in year $t$. As before, we include a linear trend and country fixed effects, and let the three $shock_{i\_}$ variables be the contemporaneous, 1-year and 2-year lagged commodity price shocks.

`[insert Table 7 here]`

Table 7 Column (5) shows our results from estimating (14) using the moving average of private credit over the immediately preceding five years. In line with our model, we find that all coefficients on the $shock_{i\_}$ variables are positive, while the interaction terms with private credit enter negatively. Two-year lagged shocks are the only significant ones, perhaps suggesting that the reallocation of investment itself takes place with a lag. To gauge the importance of credit constraints, note that R&D is procyclical for low levels of financial development but a value for private credit of 60% (= 0.74/1.25) is enough to make long-term investment countercyclical with respect to twice-lagged shocks. In fact, we observe such high levels of loan availability for many countries in our sample of 70, with their number tripling to 36 between 1974 and 1999. Our results on the response of $R\&D/I$ to shocks are robust to controlling for both *ipr* and *property* (and their interactions with shocks), as well as to using the five-year lagged 5-year average of private credit (Columns (6)–(8)).

In contrast to our findings above, the share of total investment in GDP does not become more procyclical as credit constraints tighten (Table 7, Columns (1) – (4)). Shocks do not appear to be a consistent source of either stimuli or disincentives for total investment, and their interaction with private credit tends to be insignificant and not stable across different specifications. If anything, financial development may magnify the procyclicality of $I/Y$, judging by the only significant (and positive) interaction coefficients in Columns (2) and (4).

Our model makes predictions about the allocation of investment that extend beyond R&D.[19] To test our results on the transmission channel of credit constraints we take three alternative cuts at investment (results not reported). Our strongest results are for the response of structural investment to lagged shocks. We distinguish housing/construction (long-run) from machinery and equipment (short-run), and we obtain data on the share of structural in total investment for 20 OECD countries between 1960 and 2000. We find that the fraction of long-horizon investment is countercyclical but becomes (more) procyclical when credit constraints tighten, as our model predicts. We observe the same behavior for the share of office and computing machines in total imports, another potential measure of long-term investments.[20] Finally, we were able to replicate the results with an imputed measure of the share of R&D embodied in capital equipment imports using data from Caselli and Wilson (2003). However, our findings with this measure were not stable across specifications, plausibly because of the limitations of the data.[21] While these three different measures of long-run versus short-run investments suffer from different imperfections (for example, office machines may actually be used immediately and therefore considered short-horizon), we consider these findings to be broadly consistent with our earlier conclusions.

In conclusion, the evidence provides some support for the hypothesis that credit availability helps redirect resources towards long-term productivity-enhancing projects such as R&D during a downturn, translating into improved growth a year or two later.

## 6 Concluding remarks

This paper investigated how financial development affects the cyclical behavior of the composition of investment and the implications for volatility and growth. We first considered a simple model that endogenized the composition of invesmtent. We then confronted its predictions with a cross-country panel and found that, in accordance with the model, a lower degree of financial development implies a higher sensitivity of the growth rate and and the R&D-investment ratio to exogenous shocks.

The model we used in this paper was highly stylized. Nevertheless, we expect our insights to extend to more general frameworks as long as the key propagation channel – the effect of liquidity

[19] Walde and Woitek (2004) find that the *level* of R&D expenditure tends to be procyclical in the G7 countries between 1973 and 2000. (See also Walde, 2004.) In contrast, we focus on the cyclical variation of R&D as a share of total investment.

[20] Surprisingly, however, the only statistically significant relationships we observe with computer imports are for shocks lagged by 5 to 10 years.

[21] For example, we were only able to construct an imputed value for the R&D embodied in capital imports for every fifth year between 1980 and 1995, which left us with roughly 60 countries and 3 data points per country. This made allowing for a linear trend or country fixed effects difficult and prevented an analysis with annual lagged shocks.

risk on long-term productivity-enhancing investments – is preserved. Indeed, an important direction for future research would be to embed this mechanism to a full-fledged RBC model. One could then examine in more detail the implications of our insights for the endogenous cyclical variation of the Solow residual and the impulse responses to exogenous productivity/demand shocks.[22]

Finally, turning to policy implications, our findings suggest that the cost of business cycles may be more severe in countries with lower financial development, but at the same time the effectiveness of countercyclical fiscal or monetary policies might be higher. We plan to explore these issues in future research.

## References


[1] Acemoglu, Daron, and Zilibotti, Fabrizio (1997), "Was Prometheus Unbound by Chance? Risk, Diversification, and Growth," *Journal of Political Economy* 105, 709-751.

[2] Aghion, Philippe, and Peter Howitt (1998), *Endogenous Growth Theory*, MIT press, Cambridge, MA.

[3] Aghion, Philippe, and Gilles Saint-Paul (1998), "Virtues of Bad Times: Interaction Between Productivity Growth and Economic Fluctuations," *Macroeconomic Dynamics* 2, 322-344.

[4] Aghion, Philippe, Abhijit Banerjee and Thomas Piketty (1999), "Dualism and Macroeconomic Activity," *Quarterly Journal of Economics* 114, 1359-1397.

[5] Angeletos, George-Marios (2004), "Uninsured Idiosyncratic Investment Risk and Aggregate Saving," MIT mimeo.

[6] Banerjee, Abhijit, and Andrew Newman (1993), "Occupational Choice and the Process of Development," *Journal of Political Economy* 101(2).

[7] Barlevy, Gadi (2004), "On the Timing of Innovation in Stochastic Schumpeterian Growth Models," NBER Working Paper 10741

[8] Barro, Robert, and Jong Wha Lee (1996), "International Measures of Schooling Years and Schooling Quality," *American Economic Review* 86(2), 218-23.


[22] Our results suggest that "demand shocks" in one period may generate "productivity shocks" in subsequent periods by affecting long-term productivity-enhancing investments. Thus, one needs be cautious in the interpretation of the results in the recent VAR and quantitative RBC literatures (e.g., Gali and Rabanal, 2004, Chari, Kehoe, and McGrattan 2004).

[9] Bernanke, Ben, and Mark Gertler (1989), "Agency Costs, Net Worth, and Business Fluctuations," *American Economic Review* 79, 14-31.

[10] Blattman, Christopher, Jason Hwang and Jeffrey Williamson (2004), "The Impact of the Terms of Trade on Economic Development in the Periphery, 1870-1939: Volatility and Secular Change", NBER Working Paper 10600.

[11] Caballero, Ricardo, and Mohamad Hammour (1994), "The Cleansing Effect of Recessions," *American Economic Review* 84(5), 1350-68.

[12] Caselli, Francesco, and Daniel Wilson (2003), "Importing Technology," *Journal of Monetary Economics*, forthcoming.

[13] Chari, V.V., Patrick Kehoe, and Ellen McGrattan (2004), "Are Structural VARs Useful Guides for Developing Business Cycle Theories," Federal Reserve Bank of Minneapolis Working Paper 631.

[14] Francois, Patrick, and Huw Lloyd-Ellis (2003), "Animal Spirits Through Creative Destruction", *American Economic Review,* 93, 530-550.

[15] Gali, Jordi, and Pau Rabanal (2004), "Technology Shocks and Aggregate Fluctuations: How Well does the RBC Model Fit Postwar U.S. Data?," NBER Macroeconomics Annual, forthcoming.

[16] Gali, Jordi, and Mohamad Hammour (1991), "Long-run Effects of Business Cycles," Columbia University mimeo.

[17] Gavin, M., and Ricardo Hausmann (1996), "Make or Buy: Approaches to Financial Market Integration," Inter-American Development Bank Working Paper 337.

[18] Ginarte, Juan, and Walter Park (1997), "Determinants of Patent Rights: a Cross-National Study," *Research Policy* 26(3), 283-301.

[19] Hall, Robert (1991), "Recessions as Reorganization," NBER Macroeconomics Annual.

[20] Heston, Alan, Robert Summers, and Bettina Aten (2002), "Penn World Tables Version 6.1," Center for International Comparisons at the University of Pennsylvania.

[21] Holmstrom, Bengt, and Jean Tirole (1998), "Private and Public Supply of Liquidity," *Journal of Political Economy* 106, 1-40.

[22] Jones, Larry, Rodolfo Manuelli, and Ennio Stacchetti (2000), "Technology and Policy Shocks in Models of Endogenous Growth," Federal Reserve Bank of Minneapolis Working Paper 281.

[23] Kaldor, Nicholas (1954), "The Relation of Economic Growth and Cyclical Fluctuations," *Economic Journal* 64(253), 53-71.

[24] King, Robert, and Ross Levine (1993), "Finance and Growth: Schumpeter Might Be Right," *Quarterly Journal of Economics* 108(3), 717-737.

[25] King, Robert, and Sergio Rebelo (1993), "Transitional Dynamics and Economic Growth in the Neoclassical Model," *American Economic Review* 83(4), 908-31.

[26] Kiyotaki, Nobuhiro, and John Moore (1997), "Credit Cycles," *Journal of Political Economy* 105(2), 211-48.

[27] Koren, Miklos, and Silvana Tenreyro (2004), "Diversification and Development", mimeo Harvard University and Federal Reserve Bank of Boston.

[28] Levine, Ross (1997), "Financial Development and Economic Growth: Views and Agenda," *Journal of Economic Literature* 35, 688-726.

[29] Levine, Ross, Thorsten Beck, and Asli Demirguc-Kunt (2001), "A New Database on the Structure and Development of the Financial Sector," *World Bank Economic Review.*

[30] Levine, Ross, Norman Loyaza, and Thorsten Beck (2000), "Financial Intermediation and Growth: Causality and Causes," *Journal of Monetary Economics* 46(1), 31-77.

[31] Obstfeld, Maurice (1994), "Risk-Taking, Global Diversification, and Growth," *American Economic Review* 84, 1310-1329.

[32] Ramey, Garey, and Valerie Ramey (1995), "Cross-Country Evidence on the Link Between Volatility and Growth," *American Economic Review* 85(5), 1138-51.

[33] Shleifer, Andrei (1986), "Implementation Cycles," *Journal of Political Economy* 94(6), 1163-90.

[34] Stadler, George (1990), "Business Cycle Models with Endogenous Technology," *American Economic Review* 80(4), 763-78.

[35] Walde, Klaus (2004), "Endogenous Growth Cycles," *International Economic Review*, forthcoming.

[36] Walde, Klaus, and Ulrich Woitek (2004), "R&D Expenditure in G7 Countries and the Implications for Endogenous Fluctuations and Growth," *Economics Letters* 82, 91-97.

**Table 1. Ramey-Ramey revisited**

Dependent variable: avg. growth, 1960-1995

| | No investment | | | | With investment | | | |
|---|---|---|---|---|---|---|---|---|
| | Whole sample | | OECD countries | | Whole sample | | OECD countries | |
| Independent variable: | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| *initial income* | -0.0019 | -0.0175 | -0.0110 | -0.0258 | -0.0094 | -0.0163 | -0.0123 | -0.0258 |
| | (-0.69) | (-5.66)*** | (-3.49)*** | (-7.47)*** | (-3.89)*** | (-5.98)*** | (-4.25)*** | (-6.99)*** |
| *volatility* | -0.2796 | -0.2641 | 0.0370 | -0.2939 | -0.1829 | -0.2208 | 0.0142 | -0.2899 |
| | (-2.63)*** | (-2.78)*** | (0.22) | (-1.44) | (-2.14)** | (-2.63)** | (0.09) | (-1.33) |
| *investment/GDP* | | | | | 0.1742 | 0.0963 | 0.0662 | 0.0058 |
| | | | | | (6.47)*** | (3.96)*** | (2.43)** | (0.17) |
| *pop growth* | | -0.0085 | | -0.0011 | | -0.0075 | | -0.0008 |
| | | (-3.53)*** | | (-0.39) | | (-3.54)*** | | (-0.25) |
| *sec school enrollment* | | 0.0116 | | 0.0050 | | 0.0015 | | 0.0047 |
| | | (0.89) | | (0.90) | | (0.13) | | (0.77) |
| *government size* | | -0.00020 | | -0.00019 | | -0.00025 | | -0.00014 |
| | | (-0.58) | | (-0.51) | | (-0.82) | | (-0.29) |
| *inflation* | | 0.0003 | | -0.0011 | | 0.0002 | | -0.0010 |
| | | (2.45)** | | (-1.83)^ | | (1.89)* | | (-1.07) |
| *black market premium* | | -0.0127 | | -0.0414 | | -0.0123 | | -0.0382 |
| | | (-1.61) | | (-0.44) | | (-1.78)* | | (-0.37) |
| *trade openness* | | 0.00012 | | -0.00008 | | 0.00010 | | -0.00008 |
| | | (2.25)** | | (-1.45) | | (2.14)** | | (-1.30) |
| *intell property rights* | | 0.0003 | | -0.0019 | | 0.0004 | | -0.0018 |
| | | (0.14) | | (-0.70) | | (0.21) | | (-0.57) |
| *property rights* | | 0.0030 | | 0.0004 | | 0.0018 | | 0.0006 |
| | | (2.67)*** | | (0.35) | | (1.74)* | | (0.37) |
| *R-squared* | 0.0969 | 0.6018 | 0.4194 | 0.9367 | 0.4472 | 0.7013 | 0.5515 | 0.9370 |
| *N* | 70 | 59 | 24 | 19 | 70 | 59 | 24 | 19 |

*Note: Dependent variable is average growth over the 1960-1995 period. All regressors are averages over the 1960-1995 period, except for intellectual and property rights which are for 1970-1995 and 1970-1990 respectively. Initial income and secondary school enrollment are taken for 1960. Constant term not shown. t-statistics in parenthesis. ***,**,*,^ significant at the 1%, 5%, 10% and 11% respectively.*

**Table 2. Growth, volatility and credit constraints: basic specification**

Dependent variable: avg. growth, 1960-1995

| | No investment | | | | With investment | | | |
|---|---|---|---|---|---|---|---|---|
| | Whole sample | | OECD countries | | Whole sample | | OECD countries | |
| Independent variable: | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| *initial income* | -0.0071 | -0.0174 | -0.0177 | -0.0256 | -0.0103 | -0.0159 | -0.0173 | -0.0256 |
| | (-2.56)** | (-5.77)*** | (-6.69)*** | (-6.32)*** | (-4.10)*** | (-5.70)*** | (-6.55)*** | (6.01)*** |
| *volatility* | -0.4129 | -0.5098 | -0.5165 | -0.5196 | -0.3012 | -0.4245 | -0.5446 | -0.5607 |
| | (-3.06)*** | (-3.33)*** | (-1.73)* | (-1.14) | (-2.52)** | (-2.98)*** | (-1.83)* | (-1.16) |
| *private credit* | -0.00005 | -0.00016 | -0.00019 | -0.00006 | -0.00008 | -0.00020 | -0.00021 | -0.00008 |
| | (-0.29) | (-0.98) | (-1.26) | (-0.29) | (-0.60) | (-1.34) | (-1.39) | (-0.37) |
| *volatility*private credit* | 0.0113 | 0.0090 | 0.0080 | 0.0040 | 0.0069 | 0.0069 | 0.0083 | 0.0049 |
| | (2.59)** | (2.15)** | (1.67)^ | (0.63) | (1.76)* | (1.78)* | (1.73)^ | (0.72) |
| *investment/GDP* | | | | | 0.1420 | 0.0857 | 0.0270 | 0.0218 |
| | | | | | (4.68)*** | (3.20)*** | (1.13) | (0.63) |
| *pop growth* | | -0.0081 | | 0.0005 | | -0.0076 | | 0.0018 |
| | | (-3.55)*** | | (0.17) | | (-3.64)*** | | (0.48) |
| *sec school enrollment* | | 0.0037 | | 0.0064 | | -0.0040 | | 0.0056 |
| | | (0.28) | | (1.15) | | (-0.33) | | (0.92) |
| *government size* | | -0.00001 | | 0.00006 | | -0.00013 | | 0.00027 |
| | | (-0.04) | | (0.14) | | (-0.43) | | (0.51) |
| *inflation* | | 0.0003 | | -0.0004 | | 0.0002 | | 0.0001 |
| | | (2.78)*** | | (-0.52) | | (1.91)* | | (0.11) |
| *black market premium* | | -0.0072 | | -0.0380 | | -0.0082 | | -0.0218 |
| | | (0.91) | | (-0.34) | | (-1.14) | | (-0.18) |
| *trade openness* | | 0.00011 | | -0.00004 | | 0.00009 | | -0.00003 |
| | | (2.06)** | | (-0.62) | | (1.98)* | | (-0.36) |
| *intell property rights* | | 0.0013 | | -0.0015 | | 0.0018 | | -0.0007 |
| | | (0.50) | | (-0.50) | | (0.76) | | (-0.22) |
| *property rights* | | 0.0023 | | 0.0003 | | 0.0018 | | 0.0009 |
| | | (1.94)* | | (0.23) | | (1.64)^ | | (0.57) |
| *F-test (volatility terms)* | 0.0103 | 0.0051 | 0.2462 | 0.4122 | 0.0489 | 0.0105 | 0.2157 | 0.4580 |
| *F-test (credit terms)* | 0.0001 | 0.0310 | 0.0690 | 0.3993 | 0.0814 | 0.2120 | 0.1125 | 0.3875 |
| *R-squared* | 0.3141 | 0.6576 | 0.7894 | 0.9534 | 0.4889 | 0.7212 | 0.8049 | 0.9569 |
| *N* | 70 | 59 | 22 | 19 | 70 | 59 | 22 | 19 |

*Note: Dependent variable is average growth over the 1960-1995 period. All regressors are averages over the 1960-1995 period, except for intellectual and property rights which are for 1970-1995 and 1970-1990 respectively. Initial income and secondary school enrollment are taken for 1960. Constant term not shown. t-statistics in parenthesis. P-values from an F-test of the joint significance of volatility terms (volatility and volatility*credit) and credit terms (credit and volatility*credit) reported. ***,**,*,^ significant at the 1%, 5%, 10% and 11% respectively.*

**Table 3. Growth, volatility and credit constraints: sensitivity analysis**

| Dependent variable: avg. growth, 1960-1995 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Credit constraints var.: | private credit | | liquid liabilities | | bank assets | | private credit$_{1960}$ | |
| Independent variable: | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| *initial income* | -0.0071 | -0.0174 | -0.0062 | -0.0166 | -0.0076 | -0.0173 | -0.0042 | -0.0146 |
| | (-2.56)** | (-5.77)*** | (-2.93)*** | (-5.90)*** | (-2.95)*** | (-5.59)*** | (-1.36) | (-5.46)*** |
| *volatility* | -0.4129 | -0.5098 | -0.6781 | -0.5554 | -0.6441 | -0.4981 | -0.5722 | -0.1904 |
| | (-3.06)*** | (-3.33)*** | (-3.72)*** | (-2.97)*** | (-4.03)*** | (-2.78)*** | (-3.71)*** | (-1.52) |
| *credit* | -0.00005 | -0.00016 | 0.00000 | -0.00004 | -0.00016 | -0.00021 | -0.00048 | -0.00023 |
| | (-0.29) | (-0.98) | (-0.03) | (-0.22) | (-0.88) | (-0.96) | (-1.97)** | (-1.27) |
| *volatility*credit* | 0.0113 | 0.0090 | 0.0122 | 0.0077 | 0.0162 | 0.0085 | 0.0204 | 0.0083 |
| | (2.59)** | (2.15)** | (2.96)*** | (1.90)* | (3.41)*** | (1.61)^ | (3.07)*** | (1.74)* |
| Controls: | | | | | | | | |
| *pop growth, sec enroll* | no | yes | no | yes | no | yes | no | yes |
| *Levine et al controls* | no | yes | no | yes | no | yes | no | yes |
| *property rights* | no | yes | no | yes | no | yes | no | yes |
| *R-squared* | 0.3141 | 0.6576 | 0.5058 | 0.6864 | 0.3924 | 0.6328 | 0.2263 | 0.7232 |
| *N* | 70 | 59 | 70 | 59 | 70 | 59 | 60 | 52 |

*Note: Dependent variable is average growth over the 1960-1995 period. All regressors are averages over the 1960-1995 period, except for intellectual and property rights which are for 1970-1995 and 1970-1990 respectively. Initial income and secondary school enrollment are taken for 1960. In columns (7) and (8) the initial 1960 value of private credit is used. Private credit is defined as the value of credits by financial intermediaries to the private sector, divided by GDP. Liquid liabilities represents currency plus demand and interest-bearing liabilities of banks and non-bank financial intermediaries, dividided by GDP. Bank assets is the value of all credits by banks (but not other financial intermediaries). The Levine et al. controls include the share of government in GDP, inflation, trade openness, and the black market premium. Property rights refer to both intellectural and overall property rights. Constant term not shown. t-statistics in parenthesis. ***,**,*,^ significant at the 1%, 5%, 10% and 11% respectively.*

**Table 4. The response of growth to terms of trade and commodity price shocks: 5-year averages**

Dependent variable: 5-year avg. growth

| | Terms of trade shocks | | | | Price commodity shocks | | | |
|---|---|---|---|---|---|---|---|---|
| | private credit$_t$ | | initial credit | lagged credit | private credit$_t$ | | initial credit | lagged credit |
| | OLS | FE | FE | FE | OLS | FE | FE | FE |
| Independent variable: | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| *initial income* | -0.0063 | -0.0757 | -0.0670 | -0.0899 | -0.0076 | -0.0701 | -0.0592 | -0.0751 |
| | (-2.02)** | (-8.06)*** | (-7.22)*** | (-7.12)*** | (-2.68)*** | (-8.34)*** | (-6.92)*** | (-7.00)*** |
| *shock* | 0.1402 | 0.1383 | 0.1062 | 0.1640 | 0.1297 | 0.1243 | 0.1462 | 0.1234 |
| | (3.07)*** | (3.60)*** | (2.31)** | (3.65)*** | (2.43)** | (2.68)*** | (2.45)** | (2.36)** |
| *private credit* | 0.0143 | 0.0177 | | 0.0145 | 0.0264 | 0.0387 | | 0.0325 |
| | (1.71)* | (1.09) | | (0.64) | (3.61)*** | (3.21)*** | | (1.99)** |
| *private credit*shock* | -0.3226 | -0.3509 | -0.0539 | -0.3599 | -0.2263 | -0.2119 | -0.4207 | -0.2065 |
| | (-1.89)* | (-2.24)** | (-0.23) | (-1.78)* | (-1.22) | (-1.33) | (-1.44) | (-0.99) |
| Controls: | | | | | | | | |
| *pop growth, sec enroll* | yes | yes | yes | yes | yes | yes | yes | yes |
| *R-squared* | 0.0696 | | | | 0.0867 | | | |
| *R-squared within* | | 0.3296 | 0.3418 | 0.3608 | | 0.2723 | 0.2650 | 0.2519 |
| *R-squared between* | | 0.0419 | 0.0287 | 0.0320 | | 0.0403 | 0.0322 | 0.0516 |
| *# countries (groups)* | | 73 | 57 | 70 | | 72 | 57 | 72 |
| *N* | 323 | 323 | 277 | 255 | 388 | 388 | 331 | 321 |

*Note: 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. Commodity price shocks are export-weighted changes in the price of 42 commodities. Both shocks are averaged over the corresponding 5-year interval. Private credit is concurrent 5-year average, initial 1960-1964 average or lagged (t-5,t-1) average as indicated in the column heading. Constant term not shown. t-statistics in parenthesis. ***,**,*,^ significant at the 1%, 5%, 10% and 11% respectively.*

**Table 5. The response of growth to commodity price shocks: annual panel data, fixed effects**

| Dependent variable: annual growth | private $credit_{1960}$ | (t-5,t-1) avg credit | (t-10,t-6) avg credit | 1960-2000 avg credit |
|---|---|---|---|---|
| Independent variable: | (1) | (2) | (3) | (4) |
| $shock_t$ | 0.0390 | 0.0356 | 0.0427 | 0.0449 |
| | (1.87)* | (1.87)* | (2.19)** | (2.03)** |
| $shock_{t-1}$ | 0.0610 | 0.0508 | 0.0612 | 0.0959 |
| | (2.84)*** | (2.58)*** | (3.02)*** | (4.25)*** |
| $shock_{t-2}$ | 0.0664 | 0.0772 | 0.0789 | 0.0701 |
| | (3.04)*** | (3.86)*** | (3.77)*** | (3.06)*** |
| *priv credit* | | 0.0038 | 0.0092 | |
| | | (0.45) | (0.83) | |
| *priv credit**$shock_t$ | -0.1291 | -0.0699 | -0.0929 | -0.1011 |
| | (-1.14) | (-1.06) | (-1.27) | (-1.30) |
| *priv credit**$shock_{t-1}$ | -0.2314 | -0.1039 | -0.1326 | -0.2845 |
| | (-1.97)** | (-1.53) | (-1.71)* | (-3.57)*** |
| *priv credit**$shock_{t-2}$ | -0.2446 | -0.1915 | -0.1929 | -0.1671 |
| | (-2.05)** | (-2.81)*** | (-2.39)** | (-2.07)** |
| Controls: | | | | |
| *initial income* | yes | yes | yes | yes |
| *linear trend* | yes | yes | yes | yes |
| *R-squared within* | 0.0403 | 0.0395 | 0.0374 | 0.0457 |
| *R-squared between* | 0.0298 | 0.0182 | 0.0086 | 0.0316 |
| *# countries (groups)* | 44 | 44 | 44 | 44 |
| *N* | 1653 | 1516 | 1306 | 1653 |

*Note: Dependent variable is annual growth. Annual 1960-2000 data, except where lost due to lags. Panel fixed effects estimation. $Shock_t$, $shock_{t-1}$, $shock_{t-2}$ refer to the contemporaneous, 1-year and 2-year lagged commodity price shock, as defined in the text. All regressions include a constant term and a linear trend, and control for initial income. Initial 1960 or lagged average value used for private credit, as indicated in the column heading. Columns (2)-(4) limit the sample to countries for which we have initial credit values. t-statistics in parenthesis. ***,**,* significant at the 1%, 5% and 10% respectively.*

**Table 6. The response of growth to commodity price shocks: annual panel data, property rights**

| Dependent variable: annual growth | | | | |
|---|---|---|---|---|
| Independent variable: | (1) | (2) | (3) | (4) |
| *$shock_t$* | 0.0356 | -0.0013 | -0.0064 | -0.0459 |
| | (1.87)* | (-0.03) | (-0.15) | (-0.83) |
| *$shock_{t-1}$* | 0.0508 | 0.0616 | -0.0057 | -0.0009 |
| | (2.58)*** | (1.33) | (-0.13) | (-0.02) |
| *$shock_{t-2}$* | 0.0772 | 0.0498 | 0.0603 | 0.0460 |
| | (3.86)*** | (1.27) | (1.71)* | (0.99) |
| | | | | |
| *priv credit* | 0.0038 | 0.0023 | 0.0112 | 0.0026 |
| | (0.45) | (0.19) | (0.61) | (0.14) |
| *priv credit*$shock_t$* | -0.0699 | -0.1359 | -0.1319 | -0.1136 |
| | (-1.06) | (-1.63) | (-1.11) | (-0.95) |
| *priv credit*$shock_{t-1}$* | -0.1039 | -0.0759 | -0.0690 | -0.0325 |
| | (-1.53) | (-0.93) | (-0.61) | (-0.28) |
| *priv credit*$shock_{t-2}$* | -0.1915 | -0.1765 | -0.2057 | -0.1838 |
| | (-2.81)*** | (-2.40)** | (-2.05)** | (-1.81)* |
| | | | | |
| *intell rights* | | 0.0057 | | 0.0191 |
| | | (0.70) | | (1.78)* |
| *intell rights*$shock_t$* | | 0.0417 | | 0.0173 |
| | | (1.97)** | | (0.64) |
| *intell rights*$shock_{t-1}$* | | 0.0081 | | -0.0156 |
| | | (0.38) | | (-0.57) |
| *intell rights*$shock_{t-2}$* | | 0.0194 | | -0.0005 |
| | | (1.11) | | (-0.02) |
| | | | | |
| *prop rights* | | | 0.0011 | 0.0013 |
| | | | (0.62) | (0.73) |
| *prop rights*$shock_t$* | | | 0.0175 | 0.0169 |
| | | | (1.47) | (1.34) |
| *prop rights*$shock_{t-1}$* | | | 0.0158 | 0.0186 |
| | | | (1.33) | (1.46) |
| *prop rights*$shock_{t-2}$* | | | 0.0056 | 0.0071 |
| | | | (0.57) | (0.67) |
| Controls: | | | | |
| *initial income* | yes | yes | yes | yes |
| *linear trend* | yes | yes | yes | yes |
| *R-squared within* | 0.0395 | 0.0968 | 0.0803 | 0.0881 |
| *R-squared between* | 0.0182 | 0.0003 | 0.0611 | 0.0519 |
| *# countries (groups)* | 44 | 43 | 43 | 43 |
| *N* | 1516 | 936 | 553 | 553 |

*Note: Dependent variable is annual growth. Annual 1960-2000 data, except where lost due to lags. Panel fixed effects estimation. $Shock_t$, $shock_{t-1}$, $shock_{t-2}$ refer to the contemporaneous, 1-year and 2-year lagged commodity price shock, as defined in the text. All regressions include a constant term and a linear trend, and control for initial income. Lagged (t-5,t-1) average used for private credit and the two property rights variables throughout. t-statistics in parenthesis. ***,**,* significant at the 1%, 5% and 10% respectively.*

**Table 7. The response of investment to commodity price shocks: annual panel data, fixed effects**

| Dependent variable: | Investment/GDP | | | | R&D/investment | | | |
|---|---|---|---|---|---|---|---|---|
| Credit and prop rights: | (t-5,t-1) avg | | | (t-10,t-6) avg | (t-5,t-1) avg | | | (t-10,t-6) avg |
| Independent variable: | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| *$shock_t$* | -2.56 | -9.19 | -27.60 | -9.14 | 0.2629 | 0.7217 | 0.5945 | 0.2863 |
| | (-0.21) | (-0.20) | (-0.59) | (-0.85) | (0.65) | (0.52) | (0.58) | (0.79) |
| *$shock_{t-1}$* | 10.06 | 22.58 | 47.85 | 12.61 | 0.0547 | 1.0157 | 0.4940 | 0.0642 |
| | (0.82) | (0.47) | (1.00) | (1.16) | (0.14) | (0.70) | (0.48) | (0.18) |
| *$shock_{t-2}$* | -7.56 | 111.51 | 148.02 | -13.19 | 0.7429 | -1.0500 | 0.0350 | 0.8298 |
| | (-0.65) | (3.09)*** | (3.89)*** | (-1.20) | (1.94)* | (-0.97) | (0.04) | (2.24)** |
| *priv credit* | 1.83 | -0.17 | -1.71 | 5.93 | -0.0583 | 0.0078 | -0.0685 | -0.0735 |
| | (1.32) | (-0.11) | (-0.77) | (3.72)*** | (-1.29) | (0.17) | (-1.41) | (-1.37) |
| *priv credit*$shock_t$* | 11.54 | 9.81 | 8.43 | 23.25 | -0.3734 | -0.2190 | -0.2459 | -0.4368 |
| | (0.62) | (0.39) | (0.34) | (1.40) | (-0.61) | (-0.29) | (-0.45) | (-0.78) |
| *priv credit*$shock_{t-1}$* | -2.23 | 0.14 | -16.62 | -3.42 | -0.0871 | -0.0220 | 0.0518 | -0.1722 |
| | (-0.12) | (0.01) | (-0.69) | (-0.20) | (-0.14) | (-0.03) | (0.10) | (-0.30) |
| *priv credit*$shock_{t-2}$* | 26.09 | 40.46 | 2.85 | 38.12 | -1.2544 | -1.2025 | -1.1847 | -1.5159 |
| | (1.46) | (2.06)** | (0.14) | (2.08)** | (-2.12)** | (-2.04)** | (-2.75)*** | (-2.45)** |
| *intell rights* | | -3.35 | -4.27 | | | 0.2276 | 0.1233 | |
| | | (-2.70)*** | (-2.91)*** | | | (6.11)*** | (3.87)*** | |
| *intell rights*$shock_t$* | | 1.35 | 5.05 | | | -0.1462 | 0.1216 | |
| | | (0.09) | (0.28) | | | (-0.32) | (0.31) | |
| *intell rights*$shock_{t-1}$* | | -5.27 | -13.09 | | | -0.3558 | -0.2452 | |
| | | (-0.34) | (-0.71) | | | (-0.76) | (-0.61) | |
| *intell rights*$shock_{t-2}$* | | -40.58 | -26.12 | | | 0.5785 | 0.0894 | |
| | | (-3.25)*** | (-1.91)* | | | (1.54) | (0.30) | |
| *prop rights* | | | 0.39 | | | | -0.0037 | |
| | | | (1.54) | | | | (-0.68) | |
| *prop rights*$shock_t$* | | | 1.02 | | | | -0.1037 | |
| | | | (0.19) | | | | (-0.87) | |
| *prop rights*$shock_{t-1}$* | | | 0.62 | | | | 0.0141 | |
| | | | (0.12) | | | | (0.13) | |
| *prop rights*$shock_{t-2}$* | | | -8.14 | | | | 0.0478 | |
| | | | (-2.00)** | | | | (0.54) | |
| Controls: | | | | | | | | |
| *linear trend* | yes | yes | yes | yes | yes | yes | yes | yes |
| *R-squared within* | 0.2535 | 0.2581 | 0.2295 | 0.2848 | 0.5053 | 0.5804 | 0.6228 | 0.5084 |
| *R-squared between* | 0.0519 | 0.1470 | 0.1016 | 0.0635 | 0.2292 | 0.1518 | 0.2325 | 0.2227 |
| *# countries (groups)* | 14 | 14 | 13 | 14 | 14 | 14 | 13 | 14 |
| *N* | 337 | 291 | 221 | 331 | 338 | 291 | 221 | 332 |

*Note: Dependent variable is investment as a share of GDP or R&D as a share of investment. Annual 1973-1997 data, except where lost due to lags. Panel fixed effects estimation. Shockt, shockt-1, shockt-2 refer to the contemporaneous, 1-year and 2-year lagged commodity price shock, as defined in the text. Lagged (t-10,t-6) or (t-5,t-1) average used for private credit, as indicated in the column heading. All regressions include a constant term and a linear trend. t-statistics in parenthesis. ***,**,* significant at the 1%, 5% and 10% respectively.*