Volatility and Growth

Financial Development and Cyclical Composition of Investment∗

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Abstract

We examine 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 one, 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. We find that a lower degree of financial development predicts a higher sensitivity of both the composition of investment and productivity growth to exogenous shocks.

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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.

Earliers studies have documented the positive correlation between financial development and economic growth. (See Levine, 1997, for a review.) In Table 2, we repeat the growth regressions

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

²The 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.
of Table 1 including the country’s level of financial development as one of the controls, but also adding its interaction with volatility. The level effect is the familiar one; the news is the strong interaction effect.

The negative correlation between volatility and growth appears to be stronger in countries with lower financial development. In column (1), for example, a one standard deviation increase in the level of financial development would reduce the impact of a 1% rise in volatility by $-0.32\% = 0.011 \times 29$. This interaction effect is robust to controlling for policy and demographics variables, as well as for the rate of investment rate.

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. 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. Hence, with complete markets, the fraction of savings allocated to long-term investment is countercyclical.

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3 Financial development is measured by the ratio of private credit to GDP; see Section 5.
4 Moreover, our empirical findings in Section 5 do not support amplification in the rate of investment.
5 An opportunity-cost effect of this kind has been emphasized by Aghion and Saint-Paul (1998) and more recently by Barlevy (2004).
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 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.\(^6\)

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); see Levine (1997) for a review. 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.\(^7\) 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

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\(^6\)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).

\(^7\)Koren and Tenreyro (2004), however, argue that, contrary to the portfolio diversification approach, less developed countries specialize in sectors with relatively higher, not lower, risks.
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 shock is realized, which threatens to reduce the return 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 \( \left[ a, \bar{a} \right] \subseteq \mathbb{R} \), unconditional mean normalized to 1, and conditional mean \( \mathbb{E}_{t-1} a_t = a_{t-1}^\rho \), 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 \( W_t^i \). In the first period of her life, the entrepreneur must decide on how to allocate her initial endowment between short-run investment, \( K_t^i \), long-term investment, \( Z_t^i \), and savings in the riskless bond, \( B_t^i \). 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 \( w_t^i = w_t^i/T_t \), \( k_t^i = K_t^i/T_t \), \( z_t^i = Z_t^i/T_t \), and \( b_t^i = B_t^i/T_t \) the “detrended” levels of short-term investment, long-term investment, and bonds holdings. The initial budget constraint thus reduces to

\[
k_t^i + z_t^i + b_t^i \leq w \tag{1}
\]

Short-term and long-term investment. Short-term investment takes only one step to complete, namely the initial investment \( K_t^i \) in the beginning of the first period, and generates output

\[
\Pi_t^i = a_t T_t \pi(k_t^i)
\]
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. 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

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8 This would introduce a complementarity in long-term investment activity which in turn would increase its countercyclicality under complete markets and also increase its procyclical under sufficiently tight borrowing constraints.
business, learning a new skill, adopting a new technology, or engaging in R&D — are largely in 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

\[
E_t[W_{t+1}]
\]

where

\[
W_{t+1} = \Pi_t + (\Pi_{t+1} - C_t) \Pi_t + (1 + r_t) B_t
\]

is the entrepreneur’s final-period wealth and \( \Pi_t \) is an indicator variable such that \( \Pi_t = 1 \) if the firm succeeds in paying for the implementation of the innovation and \( \Pi_t = 0 \) otherwise. Equivalently,

\[
W_{t+1} = w_{t+1} T_t
\]

where

\[
w_{t+1} = a_t \pi(k_t) + a_{t+1} q(z_t) \Pi_t + (1 + r_t) b_t
\]

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

\[
k_t + z_t \leq \mu w,
\]

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, \( X_t = a_t T_t \pi(k_t) + (1 + r_t) B_t \), for the purpose of covering the adjustment cost \( C_t \). 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

\[
p_t \equiv \Pr \left( c_t \leq \mu x_t \right) \equiv F \left( x_t \right),
\]

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

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

\[
\int_t \left[ k_t \right] = w.
\]
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

\[ c - a \pi(\hat{k}(a)) \leq 0, \]  

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

**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 \( \hat{T}_i^t = T_t q(z_i^t) \hat{b}_i^t \), we let the level of technology available to the next generation be

\[ T_{t+1} = \int_{t} \hat{T}_i^t = \int_{t} T_t q(z_i^t) \hat{b}_i^t. \]

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

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

which the entrepreneur maximizes over \( (k_t^i, z_t^i, b_t^i) \) subject to the budget constraint (1). 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

\[
\frac{q'(z_t)}{\pi'(k_t)} = \frac{a_t}{E_t a_{t+1}} = a_t^{1-\rho},
\]

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 (4) is satisfied. Equivalently,

\[
k_t + z_t = w,
\]

which means that total savings are acyclic. Combining (6) and (7) implies that, in general equilibrium, an increase in \(a_t\) reduces \(z_t\), increases \(k_t\) and increases \(r_t\). We thus conclude:

**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).\(^{10}\) 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 \(E_t a_{t+1}\) 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 (6) then reduces to \((k_t/z_t)^{1-\alpha} = a_t^{1-\rho}\), which together with (7) 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 \(\eta = (1 - \rho)/(1 - \alpha) > 0\). Hence, \(z_t\) is countercyclical (i.e., decreasing in \(a_t\)), whereas \(k_t\) is procyclical (i.e., increasing in \(a_t\)).

\(^9\)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.

\(^{10}\)This is related to the opportunity-cost effect stressed by Aghion and St. Paul (1998).
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 $k^i_t + z^i_t \leq \mu w$ 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 $c^i_t \leq \mu \left[ a_t \pi (k^i_t) + (1 + r_t) b^i_t \right]$. It follows that the entrepreneurs investment problem is given by the following:

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

s.t. \hspace{1cm} k^i_t + z^i_t + b^i_t \leq w

$$k^i_t + z^i_t \leq \mu w$$

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

We assume that $\pi, q, F$ are such that the objective in (8) 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 (4), $k_t + z_t = w \leq \mu w$. The first-order conditions with respect to $k^i_t$ and $z^i_t$ can then be expressed as follows:

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

$$\mathbb{E}_t a_{t+1} q'(z_t) F (\mu x_t) - \mathbb{E}_t a_{t+1} q(z_t) f (\mu x_t) \mu (1 + r_t) = 1 + r_t,$$

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

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

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

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

(10)

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 (10) 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 (9), (10), and $E_t a_{t+1} = a_t^\rho$, we infer that the equilibrium allocation of savings satisfies

$$\frac{q'(z_t)}{\pi'(k_t)} = \frac{a_t^{1-\rho-\phi}}{[\mu \pi(k_t)/\bar{c}]^\phi} + \frac{\phi q(z_t)}{\pi(k_t)} \quad (11)$$

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 cyclicity of liquidity risk. Moreover, in our model, the cyclicity 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 $1 - \rho < \phi < (1 - \alpha)/\alpha$.\textsuperscript{11} Condition (11) then reduces to

$$\psi(z_t) = \mu^\phi a_t^{\phi + \rho - 1} \quad (12)$$

where $\psi(z) = z^{1-\alpha} (w - z)^{-\phi \alpha} (w - (1 + \phi) z)^{-1}$. Clearly, $\psi(z)$ increases with $z$, whereas $\mu^\phi a_t^{\phi + \rho - 1}$ increases with $\mu$ and $a$. (12) can thus be solved for $z_t$ as an increasing function of $\mu$ and $a_t$.

\textsuperscript{11}The assumption $\phi < (1 - \alpha)/\alpha$ suffices for the objective in (8) to be strictly concave and therefore for the first-order conditions to be sufficient.
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 cyclical 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 counter-cyclical 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 $\bar{\alpha} < \bar{c}/\mu$. But, as soon as $\bar{\alpha} > \bar{c}/\mu$, 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 constraints 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. Furthermore, if $\mu > \bar{c}$, the negative effect of volatility on mean growth is higher 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 $\delta(a)$ 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 $z$. 

15
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

The starting point for this paper was the (novel) fact that the negative correlation between volatility and growth tends to be stronger in countries with lower financial development.

The model can help explain this fact in two ways: either as a spurious correlation reflecting the effect of financial development on both volatility and growth; or, more interestingly, as a causal
effect reflecting the effect of *exogenous* volatility on liquidity risk.

Whether the findings of Table 2 mean causality is an important question. If we repeat the regressions of Table 2 instrumenting the standard deviation of growth with the standard deviation of terms-of-trade or commodity-price shocks (as defined in the next subsection), the interaction term remains negative but loses significance. Hence, at this point there is no strong evidence for a *causal* interpretation of this interaction effect.\(^\text{12}\)

As the examples of the previous section highlighted, however, the model in general makes ambiguous predictions about either the direct effect of exogenous volatility or the interaction effect of volatility and credit – the model can not be tested on the basis of this fact. For our empirical analysis we thus turn to the model’s strongest predictions: the amplification effect, and the propagation 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

As a measure of financial development we use private credit, defined as the value of credit extended to the private sector by banks and other financial intermediaries as a share of GDP. This is a standard indicator in the finance and growth literature and it comes from the dataset developed by Levine, Loyaza and Beck (2000). It is usually preferred to other measures of financial development because it excludes credit granted to the public sector and funds coming from central or development banks. Our results are robust to alternative measures such as liquid liabilities and bank assets as a share of GDP.

We compute annual growth as the log difference of per capita income from the Penn World Tables mark 6.1 (PWT). The measures of growth and volatility used in Table 1 in the introduction are the country-specific means and standard deviations of annual growth over the 1960-1995 period.

To test the response of the economy to exogenous shocks, we proxy the latter as follows. 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 calculate the annual inflation/deflation rate for each commodity. We next average the share of this commodity in a country’s exports in 1985, 1986, and 1987 as reported in the World Trade Analyzer (WTA).\(^\text{13}\) We then sum across all commodities’ price changes using the corresponding export shares as weights. We thus ob-

---

\(^\text{12}\) More supportive is the historical evidence in Blattman, Hwang and Williamson (2004): using panel data for 35 countries over the 1870-1939 period, they find that volatility as measured by term of trade shocks is harmful for growth in the Periphery, but not in the Core.

\(^\text{13}\) These were the earliest years for which complete data was available at the country-commodity level.
tain a country- and year-specific measure of shocks for the 1960-2000 period; we refer to this as commodity-price shocks.

A proxy of shocks more commonly used in the growth literature is terms of trade. For comparison, we thus also report some results with terms-of-trade shocks; the latter are from Barro and Lee (1997), constructed in five-year averages between 1960 and 1985. Nevertheless, we prefer commodity-price shocks because time variation in exchange rates and terms of trade is largely endogenous to the business cycle of an economy. In contrast, time variation in the price of each commodity is largely exogenous to each country; and the weights we use to aggregate across commodities vary in the cross-section but not over time. Indeed, a commodity-price shock represents an exogenous demand shock for the economy.

For the analysis on the transmission channel of credit constraints, we also need data on the composition of investments. The model makes predictions about the share of long-term productivity-enhancing investment; we proxy this by the share of R&D to total investment. Unfortunately, data availability limits our sample to 14 OECD countries between 1973-1999 for which the OECD reports spending on research and development in the ANBERD database. Data on investment as a share of GDP, on the other hand, comes from the PWT. We also try taking alternative cuts at the composition of investment, such as structural investment versus equipment and the R&D embodied in capital imports as a share of total capital imports – the latter constructed by Caselli and Wilson (2003).

When analyzing the reaction of the economy to shocks, we also control for overall property rights (property) and intellectual property rights (ipr). The former is a 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). For these variable, we use the data as compiled by Caselli and Wilson (2003).

Finally, the demographics data comes from the PWT; the schooling data from Barro and Lee (1997); and the policy variables used in Table 1 – the share of government in GDP, inflation, the black market exchange rate premium, and openness to trade – from Levine et al (2000).

5.2 Sensitivity of growth to shocks

[Comment: add interactions of $\mu$ and $y_{it}$?]

We begin by examining the sensitivity of growth to shocks in the medium run.

We consider a panel of 5-year intervals in a cross-section of over 70 countries and estimate the following specification:

$$
\Delta y_{it} = \alpha_0 + \alpha_1 \cdot y_{it} + \alpha_2 \cdot \text{shock}_{it} + \alpha_3 \cdot \text{credit}_i + + \gamma \cdot \text{credit}_i \cdot \text{shock}_{it} + \beta \cdot X_{it} + \mu_i + \varepsilon_{it}
$$

(13)
\(\Delta y\) is the average annual growth for country \(i\) in period \(t\), where a period consists of 5 consecutive non-overlapping years between 1960 and 1990. \(y_{it}\) is beginning-of-period per capita income (in logs), and \(X_{it}\) is a vector of controls. For shock, we consider either the average commodity-price shock, or the average terms-of-trade shock for the period; as discussed before, we prefer commodity-price shocks because they suffer less from endogeneity over the business cycle; we consider terms-of-trade shocks for comparison.\(^{14}\)

We consider two alternatives also for credit: the average value of private credit over the contemporaneous 5-year interval; and the average value over the entire 1960-1990 period. The concern with using the contemporaneous value of credit is that, since it varies with the business cycle, it may capture the impact of some other omitted variable which also varies with the business cycle. Note, however, that for the interaction term to be spurious a beneficial shock must be associated with both higher growth rates and lower levels of private credit, which seems unlikely. Moreover, the estimate of \(\gamma\) is robust to the introduction of either a quadratic term for shock or the interaction of \(y\) and shock, which suggest that the aforementioned type of bias is probably absent. The 1960-1990 average, on the other hand, is clearly free of this kind of bias, for it varies only in the cross section; but it may also fail to capture possible exogenous medium-run variation in the level of financial development, in which case it may be a poorer proxy than the contemporaneous value credit.

We expect the overall impact of shock on \(\Delta y\) to be positive, because an increase in shock represents an improvement in the exporting opportunities available to the country. We are most interested, however, on the interaction term of credit and shock: the model predicts \(\gamma < 0\), that is, that financial development reduces the sensitivity to exogenous shocks.

[insert Table 3 here]

The results are reported in Table 3. All columns include country-specific fixed effects and cluster the error terms by country. In Column (1) we use the commodity-price shocks and the value of private credit within the period; we find a negative but insignificant coefficient on the interaction of \(credit_{it}\) and \(shock_{it}\). Once, however, time fixed effects are added, the interaction term becomes significant; see Column (2). Columns (3) and (4) repeats the regressions of Columns (1) and (2), respectively, using the 1960-1990 average value of credit; the interaction term is now significant both with and without time fixed effects.

Time fixed effects take away the component in shock that is common to all countries in a given period. Therefore, when we include time fixed effects we are isolating the response of each country to the idiosyncratic component of shock. Our model is agnostic as to whether financial development mitigates the response to world-wide or idiosyncratic shocks, but the results in Columns (1)-(4) suggest that the latter effect is more important for median-run growth outcomes. To avoid taking

\(^{14}\)The terms of trade shock is only available for 5-year intervals between 1960 and 1985.
a stance and explore the potential differential effects of the two shock components, we conduct our analysis in the remaining of the paper both with and without time fixed effects.

For comparison, Columns (5)-(6) repeat the analysis with terms-of-trade shocks. All estimates of the interaction term are again negative, but of lower statistical significance. We are not sure how to explain this result. One possibility is that it is related to the endogeneity of terms of trade: if exchange rates and/or the volume of imports and exports adjust to mitigate the effects of changes in world prices, terms of trade may be a less appropriate proxy for exogenous shocks than the price-commodity index. Motivated by these considerations, as well as by the fact that terms-of-trade are not readily available in an annual basis, we concentrate on commodity-price shocks in the rest of the analysis.

We next turn to the sensitivity of growth to shocks in the short run. Table 4 reports the results from estimating the following specification in an annual panel of over a hundred countries between 1960 and 2000:

\[
\Delta y_{it} = \alpha_0 + \delta_0 \cdot shock_{it} + \delta_{-1} \cdot shock_{it-1} + \delta_{-2} \cdot shock_{it-2} \\
+ \gamma_0 \cdot credit_{i} \cdot shock_{it} + \gamma_{-1} \cdot credit_{i} \cdot shock_{it-1} + \gamma_{-2} \cdot credit_{i} \cdot shock_{it-2} \\
+ \alpha_c \cdot credit_{i} + \alpha_y \cdot y_{it} + \mu_i + \varepsilon_{it} 
\tag{14}
\]

Now \(\Delta y\) is annual growth, \(y\) is beginning-of-year income, and the three \(shock\) variables are the contemporaneous, 1-year lagged, and 2-year lagged commodity-price shocks. The estimation of lagged shock terms is possible because of the low autocorrelation in the commodity price shocks. As before, we include country fixed effects and cluster errors by country.

Column (1) in Table 4 uses a lagged moving average of private credit over the five years immediately preceding time \(t\); as expected, tighter credit constraints result in higher sensitivity to shocks, especially at two lags. Column (2) uses the 1960-2000 average value of credit; all interaction terms remain negative, although the ones at no and one lag are less precisely estimated.

[insert Table 4 here]

Columns (1) and (2) restrict the sample to countries in which value of private credit is above 10% of GDP in all periods. This cut-off is motivated by the concern that variation in this measure of credit within the 0-10% range is unlikely to be informative about the variation in the availability of funds. If we do not use this cut-off, as Columns (3) and (4) show, each of the interaction terms is insignificant. In contrast, the results are robust to higher cut-off values, such as 15%, 20%, or 25%. In the light of these results, we use the 10% cut-off throughout the rest of the analysis.

Column (5) and (6) consider alternative measures of credit: the lagged average value of private credit over the \((t - 6, t - 10)\) period; and the initial value of credit, computed for each country.

\(^{15}\text{ADD INFO ON THE AUTOCORRELATIONS.}\)
as the average of the first 5 years for which credit data are available. Both measures predate the commodity-price shocks and the length of a business cycle. Columns (7) and (8), on the other hand, add year fixed effects. The results are similar, although the significance of each interaction term tends to fall.

Given that shock is auto-correlated, it is no bad news for the model if each of the interaction terms alone is insignificant, as long that the combination of the three is significant. The fifth row in Table 4 thus reports the result of an F-test for the inclusion of all three interaction terms: throughout all specifications, the combination of the three interactions is significant.

We next address another concern: the possibility that our measure of private credit captures the impact of some other institutional variable, or the overall level of economic development. For example, if property rights are positively correlated with credit availability and growth reacts less to adverse shocks in countries with better property rights, the interaction terms reported in Table 4 may capture the mitigating effect of property rights rather than that of financial development.

Table 5 thus revisits the regressions of Table 4 after controlling for the impact of other institutional variables. For comparison, column (1) reproduces the first column of Table 4. Column (2) includes the interactions of shock with ipr and property. Column (3) instead includes the interaction of shock with initial income y, a proxy for the overall level of economic development. Column (4) includes all three interactions and Column (5) adds time fixed effects. Columns (6) and (7) then repeat (4) and (5) using the 1960-1990 average level of credit rather than then (t−5, t−1) average. In all specifications, the combined impact of the private-credit interaction terms remain significant. Our results also survive the inclusion of the interaction of shock with other institutional variables, such as the size of government and the black market premium (results not reported).

[insert Table 5 here]

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

The evidence presented so far supports the prediction that tighter credit leads to amplification, but does not distinguish whether the transmission channel is the composition of investment. We now examine how credit affects the sensitivity of the level and the composition of investment to shocks.

Using annual data on 14 OECD countries between 1973 and 1999, we estimate the following two regressions:

\[
R&D/I_{it} = \alpha_0 + \delta_0 \cdot shock_{it} + \delta_{-1} \cdot shock_{it-1} + \delta_{-2} \cdot shock_{it-2} \\
+ \gamma_0 \cdot credit_{i-} \cdot shock_{it} + \gamma_{-1} \cdot credit_{i-} \cdot shock_{it-1} + \gamma_{-2} \cdot credit_{i-} \cdot shock_{it-2} \\
+ \alpha_c \cdot credit_{i-} + \alpha_y \cdot y_{it} + \mu_i + \varepsilon_{it}
\]

(15)
\[ I/Y_{it} = \alpha_0 + \delta_0 \cdot \text{shock}_{it} + \delta_{-1} \cdot \text{shock}_{it-1} + \delta_{-2} \cdot \text{shock}_{it-2} \\
+ \gamma_0 \cdot \text{credit}_i \cdot \text{shock}_{it} + \gamma_{-1} \cdot \text{credit}_i \cdot \text{shock}_{it-1} + \gamma_{-2} \cdot \text{credit}_i \cdot \text{shock}_{it-2} \\
+ \alpha_c \cdot \text{credit}_i + \alpha_y \cdot y_{it} + \mu_i + \varepsilon_{it} \]  

(16)

The dependent variables are R&D as a share of total investment – our proxy for long-term growth-enhancing investment – and investment as a fraction of GDP, for country \( i \) in year \( t \). As before, we consider contemporaneous, 1-year lagged, and 2-year lagged commodity-price shocks, include country fixed effects, and cluster errors by country. Note that in the sample of countries with R&D data we never observe values of private credit below 10%.

The results from estimating (15) are reported in Table 6. Columns (1)-(3) use the moving average of private credit over the immediately preceding five years, whereas Columns (4)-(6) use the 1975-1993 average for each country Columns (2) and (5) control for the interactions of shocks with \( ipr, property, \) and initial income; Columns (5) and (6) add time fixed effects.

Across all specifications, the direct effect of shocks (\( \delta \)) is typically positive, whereas the interaction of shocks with credit (\( \gamma \)) is negative; the total effect (\( \delta + \gamma \cdot \text{credit} \)) is typically positive for countries with the lowest credit and negative for the ones with the highest credit. Moreover, the interaction terms are always jointly significant.

These findings support the prediction of the model that financial development turns the fraction of long-term investment from procyclical (i.e., positively related to shock) to countercyclical. In contrast, there is no evidence that credit constraints amplify the procyclicality of the share of total investment in GDP. As Table 7 shows, if anything, financial development magnifies the procyclicality of \( I/Y \).

The model makes predictions about the composition of investment that extend beyond R&D expenditure. We found a similar pattern – results not reported – with an imputed measure of the share of R&D embodied in capital imports using data from Caselli and Wilson (2003). However, the results were not significant in some specifications, plausibly because of limitations in the data.

Stronger results were obtained for the response of structural investment. In particular, we distinguished housing/construction – a form of long-run investment – from machinery and equipment. Using data for 20 OECD countries between 1960 and 2000, we found that the fraction of structural investment becomes more procyclical as credit tightens.

\[16\] Walde and Woiwotk (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.
6 Concluding remarks

This paper investigated how financial development affects the cyclical composition of investment and the implications for volatility and growth. We first considered a simple model that endogenized the composition of investment. We found that credit constraints make the fraction of long-term productivity-enhancing investment more procyclical, thus amplifying the cyclical variation in productivity and output even if they fail to amplify the cyclical variation in aggregate savings. We then confronted these predictions with a cross-country panel and found some evidence in favor of both amplification and the particular propagation channel.

The model used in this paper was highly stylized. Nevertheless, we expect the main insights to extend to more general frameworks as long as the key propagation channel – the effect of liquidity risk on long-term productivity-enhancing investments – is preserved. An interesting direction for future research would be to embed this mechanism to a full-fledged RBC model and examine in detail the implications for the economy’s impulse responses to exogenous productivity and demand shocks.17

Finally, our findings suggest that the effectiveness of countercyclical fiscal or monetary policies might be higher in countries with lower financial development, to the extent that such policies mitigate the impact of credit constraints. We plan to explore these issues in future research.

References


Note that the Solow residual is endogenous: demand shocks may generate productivity shocks. This may be relevant also for the recent VAR and quantitative RBC literatures (e.g., Gali and Rabanal, 2004, Chari, Kehoe, and McGrattan 2004).


Table 1. Ramey-Ramey revisited

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<th>With investment</th>
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</tr>
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<td></td>
<td>OECD countries</td>
<td>(3)</td>
</tr>
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<td>(-5.66)***</td>
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<td>-0.2796</td>
<td>-0.2641</td>
</tr>
<tr>
<td></td>
<td>(-2.63)***</td>
<td>(-2.78)***</td>
</tr>
<tr>
<td>investment/GDP</td>
<td>0.1742</td>
<td>0.0963</td>
</tr>
<tr>
<td></td>
<td>(6.47)***</td>
<td>(3.96)***</td>
</tr>
<tr>
<td>pop growth</td>
<td>-0.0085</td>
<td>-0.0011</td>
</tr>
<tr>
<td></td>
<td>(-3.53)***</td>
<td>(-0.39)</td>
</tr>
<tr>
<td>sec school enrollment</td>
<td>0.0116</td>
<td>0.0050</td>
</tr>
<tr>
<td></td>
<td>(0.89)</td>
<td>(0.90)</td>
</tr>
<tr>
<td>government size</td>
<td>-0.00020</td>
<td>-0.00019</td>
</tr>
<tr>
<td></td>
<td>(-0.58)</td>
<td>(-0.51)</td>
</tr>
<tr>
<td>inflation</td>
<td>0.0003</td>
<td>-0.0011</td>
</tr>
<tr>
<td></td>
<td>(2.45)**</td>
<td>(-1.83)^</td>
</tr>
<tr>
<td>black market premium</td>
<td>-0.0127</td>
<td>-0.0414</td>
</tr>
<tr>
<td></td>
<td>(-1.61)</td>
<td>(-0.44)</td>
</tr>
<tr>
<td>trade openness</td>
<td>0.00012</td>
<td>-0.00008</td>
</tr>
<tr>
<td></td>
<td>(2.25)**</td>
<td>(-1.45)</td>
</tr>
<tr>
<td>intell property rights</td>
<td>0.0003</td>
<td>-0.0019</td>
</tr>
<tr>
<td></td>
<td>(0.14)</td>
<td>(-0.70)</td>
</tr>
<tr>
<td>property rights</td>
<td>0.0030</td>
<td>0.0004</td>
</tr>
<tr>
<td></td>
<td>(2.67)***</td>
<td>(0.35)</td>
</tr>
</tbody>
</table>

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: 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

<table>
<thead>
<tr>
<th></th>
<th>No investment</th>
<th></th>
<th>With investment</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whole sample</td>
<td>OECD countries</td>
<td>Whole sample</td>
<td>OECD countries</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>initial income</td>
<td>-0.0071</td>
<td>-0.0174</td>
<td>-0.0177</td>
<td>-0.0256</td>
</tr>
<tr>
<td></td>
<td>(2.56)**</td>
<td>(-5.77)**</td>
<td>(-6.69)**</td>
<td>(-6.32)**</td>
</tr>
<tr>
<td>volatility</td>
<td>-0.4129</td>
<td>-0.5098</td>
<td>-0.5165</td>
<td>-0.5196</td>
</tr>
<tr>
<td></td>
<td>(-3.33)**</td>
<td>(-3.33)**</td>
<td>(-1.73)</td>
<td>(-1.14)</td>
</tr>
<tr>
<td>private credit</td>
<td>-0.00005</td>
<td>-0.00016</td>
<td>-0.00019</td>
<td>-0.00006</td>
</tr>
<tr>
<td></td>
<td>(-0.29)</td>
<td>(-0.98)</td>
<td>(-1.26)</td>
<td>(-0.29)</td>
</tr>
<tr>
<td>volatility*private credit</td>
<td>0.0113</td>
<td>0.0090</td>
<td>0.0080</td>
<td>0.0040</td>
</tr>
<tr>
<td></td>
<td>(2.59)**</td>
<td>(2.15)**</td>
<td>(1.67)^</td>
<td>(0.63)</td>
</tr>
<tr>
<td>investment/GDP</td>
<td>0.1420</td>
<td>0.0857</td>
<td>0.0270</td>
<td>0.0218</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.68)**</td>
<td>(3.20)^</td>
<td>(1.13)</td>
</tr>
<tr>
<td>pop growth</td>
<td>-0.0081</td>
<td>0.0005</td>
<td>-0.0076</td>
<td>0.0018</td>
</tr>
<tr>
<td></td>
<td>(-3.55)**</td>
<td>(0.17)</td>
<td>(-3.64)**</td>
<td>(0.48)</td>
</tr>
<tr>
<td>sec school enrollment</td>
<td>0.0037</td>
<td>0.0064</td>
<td>-0.0040</td>
<td>0.0056</td>
</tr>
<tr>
<td></td>
<td>(0.28)</td>
<td>(1.15)</td>
<td>(-0.33)</td>
<td>(0.92)</td>
</tr>
<tr>
<td>government size</td>
<td>-0.00001</td>
<td>0.00006</td>
<td>-0.00013</td>
<td>0.00027</td>
</tr>
<tr>
<td></td>
<td>(-0.04)</td>
<td>(0.14)</td>
<td>(-0.43)</td>
<td>(0.51)</td>
</tr>
<tr>
<td>inflation</td>
<td>0.0003</td>
<td>-0.0004</td>
<td>0.0002</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>(2.78)**</td>
<td>(-0.52)</td>
<td>(1.91)*</td>
<td>(0.11)</td>
</tr>
<tr>
<td>black market premium</td>
<td>-0.0072</td>
<td>-0.0380</td>
<td>-0.0082</td>
<td>-0.0218</td>
</tr>
<tr>
<td></td>
<td>(0.91)</td>
<td>(-0.34)</td>
<td>(-1.14)</td>
<td>(-0.18)</td>
</tr>
<tr>
<td>trade openness</td>
<td>0.00011</td>
<td>-0.00004</td>
<td>0.00009</td>
<td>-0.00003</td>
</tr>
<tr>
<td></td>
<td>(2.06)**</td>
<td>(-0.62)</td>
<td>(1.98)*</td>
<td>(-0.36)</td>
</tr>
<tr>
<td>intell property rights</td>
<td>0.0013</td>
<td>-0.0015</td>
<td>0.0018</td>
<td>-0.0007</td>
</tr>
<tr>
<td></td>
<td>(0.50)</td>
<td>(-0.50)</td>
<td>(0.76)</td>
<td>(-0.22)</td>
</tr>
<tr>
<td>property rights</td>
<td>0.0023</td>
<td>0.0003</td>
<td>0.0018</td>
<td>0.0009</td>
</tr>
<tr>
<td></td>
<td>(1.94)*</td>
<td>(0.23)</td>
<td>(1.64)^</td>
<td>(0.57)</td>
</tr>
</tbody>
</table>

**F-test (volatility terms)**

No investment: 0.0103, 0.0051, 0.2462, 0.4122, 0.0489, 0.0105, 0.2157, 0.4580
With investment: 0.0001, 0.0310, 0.0690, 0.3993, 0.0814, 0.2120, 0.1125, 0.3875

**R-squared**

No investment: 0.3141, 0.6576, 0.7894, 0.9534, 0.4889, 0.7212, 0.8049, 0.9569
With investment: 0.023, 0.0003, 0.0018, 0.0009

**N**

No investment: 70, 59, 22, 19
With investment: 70, 59, 22, 19

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

<table>
<thead>
<tr>
<th>Private credit measure:</th>
<th>Terms of trade shocks</th>
<th></th>
<th>Price commodity shocks</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td><strong>initial income</strong></td>
<td>-0.0757 (-6.17)***</td>
<td>-0.0841 (-5.15)***</td>
<td>-0.0610 (-5.82)***</td>
<td>-0.0656 (-4.69)***</td>
</tr>
<tr>
<td><strong>shock</strong></td>
<td>0.1383 (2.11)**</td>
<td>0.1398 (2.21)**</td>
<td>0.1349 (1.85)*</td>
<td>0.1226 (1.73)*</td>
</tr>
<tr>
<td><strong>private credit</strong></td>
<td>0.0177 (1.21)</td>
<td>0.0215 (1.43)</td>
<td></td>
<td>0.0387 (2.97)***</td>
</tr>
<tr>
<td><strong>private credit*shock</strong></td>
<td>-0.3509 (-1.39)</td>
<td>-0.3129 (-1.23)</td>
<td>-0.3641 (-1.33)</td>
<td>-0.2909 (-1.11)</td>
</tr>
</tbody>
</table>

**Controls:**
- pop growth, sec enroll: yes, yes, yes, yes, yes, yes, yes, yes
- country fixed effects: yes, yes, yes, yes, yes, yes, yes, yes
- period fixed effects: no, yes, no, yes, no, yes, no, yes

<table>
<thead>
<tr>
<th>R-squared</th>
<th>0.5730</th>
<th>0.6032</th>
<th>0.5240</th>
<th>0.5465</th>
<th>0.5355</th>
<th>0.5521</th>
<th>0.4785</th>
<th>0.4922</th>
</tr>
</thead>
<tbody>
<tr>
<td># countries (groups)</td>
<td>73</td>
<td>73</td>
<td>73</td>
<td>73</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>N</td>
<td>323</td>
<td>323</td>
<td>353</td>
<td>353</td>
<td>388</td>
<td>388</td>
<td>418</td>
<td>418</td>
</tr>
</tbody>
</table>

Note: Terms of trade shocks are 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. All variables except for private credit are averaged over 5-year non-overlapping periods. The time period is 1960-1985 in Columns (1)-(4) and 1960-1990 in Columns (5)-(8). Private credit is averaged over the concurrent 5-year period in Columns (1), (2), (5) and (6), over the 1960-1985 period in Columns (3)-(4), and over the 1960-1990 period in Columns (7)-(8). All regressions include a constant term, and cluster errors at the country level. t-statistics in parenthesis. ***, **, * significant at the 1%, 5% and 10%.
Table 4. The response of growth to commodity price shocks

<table>
<thead>
<tr>
<th>Private credit measure:</th>
<th>Baseline specifications</th>
<th>No threshold</th>
<th>Other credit measures</th>
<th>Year fixed effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(t-5,t-1) avg</td>
<td>1960-2000 avg</td>
<td>(t-10,t-6) avg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(t-5,t-1) avg</td>
<td>1960-2000 avg</td>
<td>(t-5,t-1) avg</td>
<td>(t-5,t-1) avg</td>
</tr>
<tr>
<td></td>
<td>(t-10,t-6) avg</td>
<td>(t-5,t-1) avg</td>
<td>(t-10,t-6) avg</td>
<td>1960-2000 avg</td>
</tr>
<tr>
<td>Baseline specifications</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shock t</td>
<td>-0.0301</td>
<td>0.0022</td>
<td>-0.0040</td>
<td>-0.0190</td>
</tr>
<tr>
<td></td>
<td>(-1.40)</td>
<td>(0.08)</td>
<td>(-0.19)</td>
<td>(-0.88)</td>
</tr>
<tr>
<td>Shock t-1</td>
<td>0.0336</td>
<td>-0.0020</td>
<td>0.0215</td>
<td>0.0247</td>
</tr>
<tr>
<td></td>
<td>(1.52)</td>
<td>(-0.04)</td>
<td>(1.07)</td>
<td>(1.01)</td>
</tr>
<tr>
<td>Shock t-2</td>
<td>0.0781</td>
<td>0.0775</td>
<td>0.0497</td>
<td>0.0718</td>
</tr>
<tr>
<td></td>
<td>(3.57)**</td>
<td>(2.45)**</td>
<td>(2.91)**</td>
<td>(2.92)**</td>
</tr>
<tr>
<td>Priv credit</td>
<td>0.0187</td>
<td>0.0259</td>
<td>0.0198</td>
<td>0.0178</td>
</tr>
<tr>
<td></td>
<td>(2.22)**</td>
<td>(3.00)**</td>
<td>(1.94)*</td>
<td>(1.44)</td>
</tr>
<tr>
<td>Priv credit*Shock t</td>
<td>0.1053</td>
<td>0.0120</td>
<td>0.0221</td>
<td>0.0653</td>
</tr>
<tr>
<td></td>
<td>(1.60)</td>
<td>(0.17)</td>
<td>(0.35)</td>
<td>(0.99)</td>
</tr>
<tr>
<td>Priv credit*Shock t-1</td>
<td>-0.0189</td>
<td>-0.0891</td>
<td>-0.0668</td>
<td>-0.0835</td>
</tr>
<tr>
<td></td>
<td>(-1.93)</td>
<td>(-0.80)</td>
<td>(-0.97)</td>
<td>(-1.13)</td>
</tr>
<tr>
<td>Priv credit*Shock t-2</td>
<td>-0.1920</td>
<td>-0.2235</td>
<td>-0.1080</td>
<td>-0.1904</td>
</tr>
<tr>
<td></td>
<td>(-2.58)**</td>
<td>(-2.46)**</td>
<td>(-1.78)*</td>
<td>(-2.25)**</td>
</tr>
<tr>
<td>Controls:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial income</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Country fixed effects</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Year fixed effects</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.1494</td>
<td>0.1224</td>
<td>0.1195</td>
<td>0.1479</td>
</tr>
<tr>
<td># countries</td>
<td>101</td>
<td>59</td>
<td>109</td>
<td>97</td>
</tr>
<tr>
<td>N</td>
<td>2,642</td>
<td>2,147</td>
<td>3,110</td>
<td>2,230</td>
</tr>
</tbody>
</table>

Note: Annual 1960-2000 data, except where lost due to lags. shock t, shock t-1, shock t-2 refer to the contemporaneous, 1-year and 2-year lagged commodity price shock. All regressions include a constant term, and cluster errors at the country level. Columns (1), (3), (5), (7) limit the sample to country-year observations with a credit measure above 10% of GDP. Columns (2), (4), (6), (8) limit the sample to countries for which private credit was always above 10% in the sample period. t-statistics in parenthesis. ***, **, * significant at the 1%, 5% and 10%.
Table 5. The response of growth to commodity price shocks: robustness

Dependent variable: annual growth

<table>
<thead>
<tr>
<th>Private credit measure:</th>
<th>(t-5,t-1) avg private credit</th>
<th>1960-2000 avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>shock_t</td>
<td>-0.0301</td>
<td>-0.2036</td>
</tr>
<tr>
<td></td>
<td>(-1.40)</td>
<td>(-1.07)</td>
</tr>
<tr>
<td>shock_t-1</td>
<td>0.0336</td>
<td>0.1087</td>
</tr>
<tr>
<td></td>
<td>(1.52)</td>
<td>(0.46)</td>
</tr>
<tr>
<td>shock_t-2</td>
<td>0.0781</td>
<td>0.4092</td>
</tr>
<tr>
<td></td>
<td>(3.57)**</td>
<td>(2.13)**</td>
</tr>
<tr>
<td>priv credit</td>
<td>0.0187</td>
<td>0.0185</td>
</tr>
<tr>
<td></td>
<td>(2.22)**</td>
<td>(2.85)**</td>
</tr>
<tr>
<td>priv credit*shock_t</td>
<td>0.1053</td>
<td>0.0485</td>
</tr>
<tr>
<td></td>
<td>(1.60)</td>
<td>(0.36)</td>
</tr>
<tr>
<td>priv credit*shock_t-1</td>
<td>-0.1089</td>
<td>-0.0692</td>
</tr>
<tr>
<td></td>
<td>(-1.93)*</td>
<td>(-0.35)</td>
</tr>
<tr>
<td>priv credit*shock_t-2</td>
<td>-0.1920</td>
<td>-0.3106</td>
</tr>
<tr>
<td></td>
<td>(-2.58)**</td>
<td>(-1.72)*</td>
</tr>
</tbody>
</table>

Controls:
- initial income: yes, yes, yes, yes, yes, yes, yes
- country fixed effects: yes, yes, yes, yes, yes, yes, yes
- property rights and interactions: no, yes, no, yes, yes, yes, yes
- initial income interactions: no, no, yes, yes, yes, yes, yes
- year fixed effects: no, no, no, no, yes, no, yes

R-squared: 0.1494, 0.1498, 0.2140, 0.2632, 0.2209, 0.2827
# countries: 101, 101, 101, 82, 51, 51
N: 2,642, 2,642, 2,642, 1,423, 1,092, 1,092

Note: Annual 1960-2000 data, except where lost due to lags. shock_t, shock_t-1, shock_t-2 refer to the contemporaneous, 1-year and 2-year lagged commodity price shock. All regressions include a constant term, and cluster errors at the country level. Columns (1)-(5) limit the sample to country-year observations with a credit measure above 10% of GDP. Columns (6)-(7) limit the sample to countries for which private credit was always above 10% in the sample period. t-statistics in parenthesis. ***,**,*^ significant at the 1%, 5%, 10%, and 11%.
Table 6. The response of R&D to commodity price shocks

<table>
<thead>
<tr>
<th>Private credit measure:</th>
<th>(t-5,t-1) avg</th>
<th>1973-1999 avg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>shock_t</td>
<td>-0.0270</td>
<td>1.4629</td>
</tr>
<tr>
<td></td>
<td>(-0.09)</td>
<td>(0.45)</td>
</tr>
<tr>
<td>shock_{t-1}</td>
<td>-0.2072</td>
<td>2.9007</td>
</tr>
<tr>
<td></td>
<td>(-0.80)</td>
<td>(0.89)</td>
</tr>
<tr>
<td>shock_{t-2}</td>
<td>0.5347</td>
<td>7.0955</td>
</tr>
<tr>
<td></td>
<td>(1.59)</td>
<td>(1.31)</td>
</tr>
<tr>
<td>priv credit</td>
<td>0.0967</td>
<td>0.0701</td>
</tr>
<tr>
<td></td>
<td>(0.47)</td>
<td>(0.48)</td>
</tr>
<tr>
<td>priv credit*shock_t</td>
<td>-0.0952</td>
<td>-0.0012</td>
</tr>
<tr>
<td></td>
<td>(-0.22)</td>
<td>(-0.00)</td>
</tr>
<tr>
<td>priv credit*shock_{t-1}</td>
<td>0.0682</td>
<td>-0.0019</td>
</tr>
<tr>
<td></td>
<td>(0.13)</td>
<td>(-0.01)</td>
</tr>
<tr>
<td>priv credit*shock_{t-2}</td>
<td>-1.1456</td>
<td>-0.8691</td>
</tr>
<tr>
<td></td>
<td>(-1.80)*</td>
<td>(-1.47)</td>
</tr>
</tbody>
</table>

Controls:
- initial income: yes
- country fixed effects: yes
- property rights and interactions: no
- initial income interactions: no
- year fixed effects: no

R-squared: 0.8339 0.9186 0.9311 0.8415 0.7759 0.8877
# countries: 14 14 14 14 14 14
N: 342 307 307 357 357 357

Note: Annual 1973-1999 data, except where lost due to lags. shock_t, shock_{t-1}, shock_{t-2} refer to the contemporaneous, 1-year and 2-year lagged commodity price shock. All regressions include a constant term, and cluster errors at the country level. t-statistics in parenthesis. ***, ** and * significant at the 1%, 5% and 10%.
## Table 7. The response of investment to commodity price shocks

<table>
<thead>
<tr>
<th>Private credit measure:</th>
<th>(t-5,t-1) avg</th>
<th>1973-1999 avg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>$shock_t$</td>
<td>1.71</td>
<td>262.86</td>
</tr>
<tr>
<td></td>
<td>(0.21)</td>
<td>(1.90)*</td>
</tr>
<tr>
<td>$shock_{t-1}$</td>
<td>14.05</td>
<td>619.02</td>
</tr>
<tr>
<td></td>
<td>(2.05)*</td>
<td>(2.79)**</td>
</tr>
<tr>
<td>$shock_{t-2}$</td>
<td>-4.74</td>
<td>749.28</td>
</tr>
<tr>
<td></td>
<td>(-0.51)</td>
<td>(2.51)**</td>
</tr>
<tr>
<td>priv credit</td>
<td>-0.36</td>
<td>-0.70</td>
</tr>
<tr>
<td></td>
<td>(-0.13)</td>
<td>(-0.29)</td>
</tr>
<tr>
<td>priv credit*shock$_t$</td>
<td>7.29</td>
<td>13.19</td>
</tr>
<tr>
<td></td>
<td>(0.79)</td>
<td>(1.26)</td>
</tr>
<tr>
<td>priv credit*shock$_{t-1}$</td>
<td>-4.78</td>
<td>25.17</td>
</tr>
<tr>
<td></td>
<td>(-0.39)</td>
<td>(1.86)*</td>
</tr>
<tr>
<td>priv credit*shock$_{t-2}$</td>
<td>24.76</td>
<td>56.27</td>
</tr>
<tr>
<td></td>
<td>(1.54)</td>
<td>(3.76)***</td>
</tr>
</tbody>
</table>

**Controls:**
- initial income: yes yes yes yes yes yes
- country fixed effects: yes yes yes yes yes yes
- property rights and interactions: no yes yes no yes yes
- initial income interactions: no yes yes no yes yes
- year fixed effects: no no yes no no yes

**R-squared:** 0.7137 0.7896 0.8288 0.7042 0.6932 0.8877

**# countries:** 14 14 14 14 14 14

**N:** 341 307 307 356 356 357

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*Note:* Annual 1973-1999 data, except where lost due to lags. shock$_t$, shock$_{t-1}$, shock$_{t-2}$ refer to the contemporaneous, 1-year and 2-year lagged commodity price shock. All regressions include a constant term, and cluster errors at the country level. t-statistics in parenthesis. ***,**,* significant at the 1%, 5% and 10%.