WPS6767

Policy Research Working Paper 6767

Access to Finance, Product Innovation and Middle-Income Traps

Pierre-Richard Agénor
Otaviano Canuto

The World Bank
Development Economics Vice Presidency
Office of the Chief Economist
February 2014

Policy Research Working Paper 6767

Abstract

This paper studies interactions between access to finance, product innovation, and labor supply in a two-period overlapping generations model with an endogenous skill distribution and credit market frictions. In the model lack of access to finance (induced by high monitoring costs) has an adverse effect on innovation activity not only directly but also indirectly, because too few individuals may choose to invest in skills. If monitoring costs fall with the number of successful projects, multiple equilibria may emerge, one of which, a middle-income trap, characterized by low wages in the design sector, a low share of the labor force engaged in innovation activity, and low growth. A sufficiently ambitious policy aimed at alleviating constraints on access to finance by innovators may allow a country to move away from such a trap by promoting the production of ideas and improving incentives to invest in skills.

This paper is a product of the Office of the Chief Economist, Development Economics Vice Presidency. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at ocanuto@worldbank.org or pierre-richard.agenor@manchester.ac.uk.

ACCESS TO FINANCE, PRODUCT INNOVATION AND MIDDLE-INCOME TRAPS

Pierre-Richard Agénor*
Pierre-richard.agenor@manchester.ac.uk

Otaviano Canuto**
ocanuto@worldbank.org

Keywords: access to finance; economic growth; overlapping generations models; multiple equilibria

JEL Classification Numbers: H54, O31, O41

---

*Hallsworth Professor of International Macroeconomics and Development Economics, University of Manchester, and co-Director, Centre for Growth and Business Cycle Research; and **Senior Advisor, World Bank.
We are grateful to various colleagues for helpful discussions and comments but we bear sole responsibility for the views expressed in this paper. The Appendix is available upon request.

1 Introduction

The impact of financial constraints on innovation has been the subject of much debate in recent years. The conventional view is that firms engaged in innovation may suffer from a variety of frictions that may limit their ability to resort to external finance. Assets held by these firms are mainly intangible; as a result, they may lack collateral value. For instance, spending in the form of salaries and wages for scientists and researchers, which often represent a large fraction of innovation-related activities and help to build human capital, cannot be collateralized. Furthermore, to protect their proprietary information over innovation, firms may be unwilling to offer fully transparent signals about the effectiveness of their intended innovation programs to potential lenders. Limited collateral value and information frictions may thus help to explain why some of these firms rely little on debt finance and instead fund most of their investments with their own resources or (at later stages) equity. Indeed, the high degree of information asymmetry that characterizes investment in innovation projects may induce lenders to demand higher rates of return than in the case of investments in physical assets. Thus, although information asymmetries matter for external financing of all types of investments, they may be particularly significant in limiting financing of innovation projects due to the complexity and specificity of the innovation process. Moreover, funding through equity is either costly—especially for firms whose values are determined mainly by their growth potential and hence are severely exposed to asymmetric information frictions—or simply not available, as is often the case for younger and smaller firms.[1] If financing constraints are binding for a sufficient number of innovative firms, economic growth may be adversely affected.

Although at the conceptual level there are good reasons to believe that information problems and lack of collateral value can make innovation activities more susceptible to financing frictions than other types of investment, the early evidence did not prove

[1]The inability of innovative firms to raise external capital can be mitigated in countries where venture capitalists (VCs) operate. The theoretical literature in financial economics on how VCs screen, select, and finance small firms is largely partial equilibrium in nature and focuses on the dynamics of the relationship and optimal contractual arrangements between VCs and entrepreneurs. See for instance Keuschnigg (2003) for references and a simple model of contractual arrangement with double moral hazard.

very conclusive. As noted by Hall and Lerner (2010) in a comprehensive review of the literature, although some studies provided evidence that financial frictions have a strong adverse effect upon innovation, others failed to find any significant effect. However, more recent studies have shown that the early literature suffered from several deficiencies. One problem is that in some early studies financial constraints were measured using the sensitivity of investments to internally generated cash flows; however, because they are positively correlated with expected profits, traditional cash-flow indicators may fail to identify meaningful patterns in the data. Other problems include the use of inadequate controls, the presence of bias arising from the endogeneity of the variable(s) measuring financial constraints, and sampling issues. As discussed later, more recent studies that address these econometric issues all point to significant negative effects of financial barriers on the ability of firms to engage in innovation.

Several analytical contributions have attempted to identify more precisely the channels through which inadequate access to finance may act as a constraint to innovation and, in doing so, adversely affect growth. These contributions include Galetovic (1996), De la Fuente and Marín (1996), Blackburn and Hung (1998), Morales (2003), Aghion et al. (2005), Gorodnichenko and Schnitzer (2013), and Laeven et al. (2013). De la Fuente and Marín (1996) for instance developed a model of product innovation in which efficiency of the financial system arises endogenously. Risk aversion and private information in innovation activities lead to a moral hazard problem, and this makes innovative activity unattractive for risk-averse entrepreneurs.[2] This problem, however, can be mitigated through improved monitoring, which allows financial intermediaries to offer better insurances terms. Hence, more efficient financial systems yield a higher level of innovative activity. Blackburn and Hung (1998) study an economy in which firms require external finance to engage in innovation activity but are subject to a moral hazard problem, due to the fact that the outcome of such activities is private information—only the firm itself can directly observe if the innovation activity has succeeded in producing a new blueprint. Because the solution to this problem (in standard

[2] In their model, it is the actions of firms, rather than the outcomes of projects, that are imperfectly observable by lenders. In addition, the precision of information obtained by lenders depends on the intensity of monitoring activity, and the feedback between growth and financial development occurs as a result of changes in factor prices.

Gale-Hellwig-Townsend fashion) is in terms of an incentive-compatible loan contract that involves costly monitoring, a fixed cost is introduced in the innovation sector. Financial liberalization allows financial intermediaries to diversify among a large number of projects that significantly reduces delegation costs. Lower costs of monitoring therefore spur innovation activity and economic growth.

Morales (2003) also explicitly modeled the contractual relationship between innovators (researchers) and lenders. Financial intermediaries are endowed with a monitoring technology that allows them to force researchers to exert a higher level of effort than the one they would choose in the absence of monitoring. Hence, research productivity, and the likelihood of research projects succeeding, is determined in the credit market and thus may be affected by the nature of financial contracts. The promotion of financial activities (through subsidies to financial intermediation, for instance) may therefore increase productivity in the innovation sector and enhance the economy's growth performance.[3] Aghion et al. (2005) assumed that firms can conceal the results of successful innovations and thereby avoid repaying their creditors. A low degree of creditor protection makes fraud an inexpensive option, and this limits firms' access to external finance—which in turn discourages the production of ideas.[4] Financial liberalization tends to increase hiding costs by providing better laws and institutions. This makes credit more readily available to entrepreneurs and allows them to engage in more innovation-related activities. Moreover, Aghion and Howitt (2009, Chapter 6) showed in a related setting that reducing credit constraints results in lower screening and monitoring costs, thus mitigating agency problems and increasing the frequency of innovations. Finally, Gorodnichenko and Schnitzer (2013) developed a model with monopolistic competition, financial constraints, and innovation activities, and derived

[3] In addition, Morales also found that a subsidy to financial intermediation may be more effective than a direct subsidy to research. The latter policy induces a higher research intensity that raises the growth rate. However, the tax change reduces researchers' incentives to exert effort, which implies higher monitoring costs and lower productivity in the innovation sector. This mitigates the positive growth effect of the research subsidy to a point where, for a high enough subsidy rate, the growth effect can become negative.

[4] Acharya and Subramanian (2009) have argued, on the contrary, that a low degree of creditor protection discourages the production of ideas. But they do so in a model in which innovators may choose between debt and equity, a questionable assumption for the type of countries that are the focus of this paper.

two important results. First, the stronger *internal* financial constraints (induced by negative liquidity shocks) are, the lower is the investment in innovation or knowledge creation activities in general. Second, the more severe *external* financial constraints (that is, the larger the cost of external finance) are, the more pronounced is the impact of a negative liquidity shock on innovation. Put differently, even though firms may tend to use internal funds to finance innovation projects, the cost of external finance may also alter incentives to innovate, because it can affect the firms's production costs and overall profitability.

This paper presents an analysis of how interactions between access (or lack thereof) to finance, product innovation, and labor supply can generate multiple equilibria, one of which is defined as a *middle-income trap* characterized by low growth in output and low productivity. Studies by Eichengreen et al. (2012, 2013), Felipe et al. (2012), Jimenez et al. (2012), and Aiyar et al. (2013), have indeed documented the existence of these traps.[5] In a previous contribution (see Agénor and Canuto (2012)), we emphasized the role of access (or lack thereof) to infrastructure, especially advanced information and telecommunications technologies, and their interaction with labor supply decisions, as a source of middle-income traps. In the present paper we shift our emphasis to access to finance, while continuing to account for the endogeneity of the decision to invest in skills and operate in innovation activities. As it turns out, this is important to understand the interactions between finance and innovation.

More specifically, we combine elements of our previous framework with some features of the analysis presented in Morales (2003), in order to bring forth the role of credit market frictions. Our analysis shows that if research activity involves borrowing from financial intermediaries and monitoring is costly, high intermediation costs may adversely affect innovation. This is in line with some of the other contributions discussed earlier. In addition, if monitoring costs are high, fewer individuals may choose to invest in skills and engage in design activities. The reason is that high monitoring costs lead to lower wages in the design sector, which in turn lead (for a given cost of education) to reduced incentives to invest in skills and thus a lower share of the labor force engaged in research. From that perspective, lack of access to finance not only has

[5] See Im and Rosenblatt (2013) for a critical review of the evidence.

a direct, adverse effect on innovation activity and growth, but also an indirect effect that operates in the same direction. We also show that if unit monitoring costs fall with the number of successful projects (as a result of information externalities, for instance), multiple equilibria may emerge—one of which, a middle-income trap, characterized by low wages in the design sector, a low share of the labor force engaged in innovation activity, and low growth. A sufficiently ambitious policy aimed at alleviating financial constraints—through the development of capital markets rather than government subsidies, which may be difficult to target effectively—may allow a country to move away from such a trap, not only by reducing the cost of finance but also by improving incentives to invest in skills and promoting the production of ideas.

The focus of our analysis is on middle-income countries, where we believe that accounting for the labor market effects of access to finance (or lack thereof) is particularly important to understand the interactions between financial intermediation, innovation, and growth. In these countries, the supply of highly-qualified labor remains relatively limited, creating therefore another constraint on innovation activity. By contrast, in developed countries the issue may be less about the *quantity* of highly-skilled workers and more about the *allocation* of talent—an issue that we addressed in a previous contribution—and the provision of adequate incentives to engage in risky entrepreneurial activities. Nevertheless, our analysis also has some relevance for slow-growing industrial countries. Indeed, there is compelling empirical evidence to suggest that in many of these countries access to finance remains an equally important constraint on the innovation activity of small and medium-sized firms. Inadequate access to finance may therefore be the source of a slow-growth equilibrium, just as with the middle-income trap that we characterize in our analysis. In such conditions, a forceful policy aimed at promoting access to finance is also essential to escape from a low-growth equilibrium and put the economy on a path that would allow it to converge to a high-growth, high-innovation equilibrium.

The paper proceeds as follows. The recent evidence on access to finance and innovation is reviewed in Section 2. Although these studies pertain mostly to industrial countries, some also include developing countries.[6] The model is described in Section

[6] Empirical studies and enterprise surveys have indeed documented that lack of access to finance is

3. Section 4 defines the equilibrium and analyzes its properties. Section 5 discusses the conditions under which multiple equilibria may emerge, when unit monitoring costs are endogenous. Section 6 draws together the policy implications of the analysis, and the final section offers some concluding remarks.

2 Finance and Innovation: Recent Evidence

Recent contributions on the link between access to finance and innovation include Savignac (2008), Ang (2010, 2011), Ayyagari et al. (2011), Ilyina and Samaniego (2011), Brown et al. (2012), Efthyvoulou and Vahter (2012), Hottenrott and Peters (2012), Maskus et al. (2012), Popov and Roosenboom (2012), Silva and Carreira (2012), Gorodnichenko and Schnitzer (2013), and Hsu et al. (2014).

Using a direct measure of financial constraints faced by French firms, Savignac (2008) estimated simultaneously the probability to have innovative activities and the probability to face financial constraints. She also accounted for the endogeneity of the financial constraint variable, by relating it to firms' *ex ante* financing structure and economic performance. She found that financial constraints significantly reduced the likelihood of firms engaging in innovative activities. Similarly, Efthyvoulou and Vahter (2012) found that lack of appropriate sources of finance is an important hampering factor to innovation performance across European countries, whereas Hottenrott and Peters (2012) found that external financial constraints are more binding for R&D and innovation activities of small firms.

Ayyagari et al. (2011) exploited the responses of some 17,000 firms in 47 countries—many of them low- and middle-income economies—to questions on enterprise innovation. Taking an average of each firm's responses to the innovation-related questions, they assembled a range of country- and firm-level variables likely to be associated with firm innovation, including information about the structure of each firm's financing. Accounting for various control variables and controlling for reverse causality by using instrumental variable techniques, they found that firms' use of external finance was

one of the most important constraints that formal private firms—small and medium-size alike—face in developing countries. See for instance World Bank (2008, 2012), Dinh and Clarke (2012), and International Finance Corporation (2013).

associated with more innovation.

In the same vein, Ilyina and Samaniego (2011) found, using cross-country data, that industries that grow faster in more financially developed countries display greater research and development (R&D) intensity and investment lumpiness, indicating that well-functioning financial markets direct resources towards industries where growth is driven by R&D. In a study of 16 European countries, Brown et al. (2012) also found strong evidence that the availability of finance does matter for R&D, once firms' efforts to smooth R&D with cash reserves and firms' use of external equity finance are directly controlled for. They conclude that stock market development and liberalization can promote economic growth by increasing firm-level innovative activity.

Cross-country studies by Ang (2011), Maskus et al. (2012), and Hsu et al. (2014) go in the same direction regarding the link between financial development and innovation. Using data for 44 developed and developing countries over the period 1973-2005, Ang (2011) found that financial development (as measured by the ratio of private sector credit to GDP) has a positive impact on the accumulation of ideas (as measured by the growth of patents), possibly by mitigating the effect of financial constraints.

In an analysis of the performance of 22 manufacturing industries in 18 OECD countries, Maskus et al. (2012) found that bank credit and stock-market capitalization have similar effects, in terms of magnitude, on R&D intensities (defined as industry-level R&D as a share of output). Financial development and financial access are key reasons why firms in countries with deeper markets invest more in R&D than do their counterparts in other countries. They also found that industries with low proportions of tangible capital tend to be those with higher proportions of intellectual capital. If the R&D intensities of those sectors also rise with capital-market sophistication, then financial development would support higher innovation in knowledge-based activities. In the same vein, Hsu et al. (2014) found that equity market development tends to promote innovation in industries that are not only more dependent on external finance but also more high-tech intensive.

De Mel et al. (2009), Ang (2010), and Silva and Carreira (2012) are three country case studies on the link between access to finance and innovation. Using survey data for Sri Lanka, De Mel et al. (2009) found that access to finance (as measured by the presence of a bank loan) is positively correlated with the capacity to innovate. However, this correlation could also reflect unmeasured productivity attributes of the firm that are correlated with both its ability to innovate and its decision to receive a loan. Using data for the Republic of Korea over the period 1967-2005, Ang (2010) found a significant long-run relationship between knowledge production and financial liberalization. By analyzing the impact of a self-assessed measure of constraints upon R&D investment, Silva and Carreira (2012) found that, when the endogeneity problem associated with that variable is taken into account, financial constraints significantly decrease the amounts invested in R&D in Portugal. Furthermore, also resorting to the same direct measure, they found that innovation (in a broad sense) is significantly hampered by financial constraints only once they allow for a joint specification of errors of both equations.

Studies by Hirukawa and Ueda (2011), Popov and Roosenboom (2012), and Faria and Barbosa (2014) focus more specifically on the link between venture capital (VC) and innovation. The key question asked by Hirukawa and Ueda (2011) is related to the causal relationship between VC and innovation: does VC investment make the invested firms innovative, or do innovative firms attract VC investment? This in turn rests on the validity of the "VC-first" (VC induces innovation) versus "innovation-first" (the arrival of new technology that spurs the demand for VC) hypotheses. They argue that the earlier literature (reviewed by Sharpe (2009) and Hall and Lerner (2010)) was often viewed as being supportive of the VC-first hypothesis. However, they provide a more careful analysis of the causality between VC and innovation by studying two types of VC investments (the first and follow-on investments) and two innovation indicators (patent counts and TFP growth) in a panel of U.S. manufacturing industries. They found distinct results for each indicator and each type of VC investment. In relation to patent growth in the first VC investment, there is little evidence to support either the innovation-first or the VC-first hypotheses but VC appears to slow down patent growth one year later.

Popov and Roosenboom (2012) provide apparently the first cross-country evidence of the effect of VC investment on patented inventions. Using a panel of 21 European countries and 10 manufacturing industries covering the period 1991-2005, they study the effect of VC, relative to R&D, on the number of granted patents. They address concerns about causality by exploiting variations across countries and over time in private equity fund-raising and in the structure of private equity funds. They found that the effect of VC is significant only in the subsample of high-VC countries, where the ratio VC/R&D has averaged around 3.9 percent between 1991 and 2005 and VC has accounted for 10.2 percent of industrial innovation during that period. They also found that VC is relatively more successful in fostering innovation in countries with lower barriers to entrepreneurship, with a tax and regulatory environment that promotes venture capital investment, and with lower taxes on capital gains. Faria and Barbosa (2014) also found robust empirical support for a positive impact of VC on innovation on a sample of 17 European countries.

The thrust of the foregoing review is therefore that more recent empirical studies, which address a range of econometric problems that plagued the earlier literature (inadequate controls, endogeneity bias, direction of causality, sampling issues, and so on) tend to a large extent to support the existence of significant negative effects of financial barriers and lack of finance on the ability of firms—especially the smaller ones—to engage in innovation. This is especially so for studies that use direct indicators based on firm's own assessments. We now turn to a formal analysis of the links between finance, innovation and growth, and study how the existence of finance constraints can be associated with multiple equilibria.

3 The Model

The economy that we consider is populated by individuals with different innate abilities, who live for two periods, adulthood and old age. Population is constant. Each individual is endowed with one unit of time in the first period of life, and zero unit in old age. Wages are the only source of income in adulthood.

There are three production sectors in the economy: the first produces a final good (manufacturing, for simplicity), the second intermediate inputs (which depreciate fully after use), and the third designs. As in Romer (1990), each new design involves the production of a new intermediate input, using a technology similar to the one used to produce the final good. Firms producing the final good use unskilled labor, physical capital, and intermediate goods, whereas firms in the design sector (or researchers, for short) use only skilled labor. The final good can be either consumed in the period it is produced, or stored to yield physical capital at the beginning of the following period. Innovation activity is risky and requires external finance of researchers' wages, as they do not accept uncertain returns. Therefore, access to finance partly determines the size of the innovation sector and the allocation of labor across sectors. As in Morales (2003), the contractual relationship between researchers and lenders involves monitoring; the monitoring technology that financial intermediaries are endowed with allows them to force researchers to exert a higher level of effort than the one they would choose in the absence of monitoring.

3.1 Households

Individuals have identical preferences but they are born with different abilities, indexed by a. Abilities are instantly observable by all and follow a continuous distribution with density function $f(a)$ and cumulative distribution function $F(a)$, with support $(0,1)$. For tractability, a is assumed to be uniformly distributed on its support. Each individual maximizes utility and decides whether to enter the labor force as an unskilled worker or (following a training period) as a skilled worker.

An unskilled individual can work only in the final good sector, at the wage w_t^U, whereas only skilled individuals can work in the design sector (identified with superscript R), at the wage w_t^S. For that, he/she must also engage at a cost in schooling activity and acquire additional, specialized skills, which in turn requires spending a fraction $\varepsilon \in (0,1)$ of his or her time endowment at the beginning of adulthood.[7] There are no barriers (financial or otherwise) to entry in the design sector, so any skilled individual can work there as a researcher if he or she is willing to do so.

Let $c_{t+j}^{h,t}$ denote consumption at period $t+j$ of an individual working at wage w_t^h, where $h = U, S$, born at the beginning of period t, with $j = 0, 1$. The individual's

[7] For a conceptually similar setup, see for instance Galor and Moav (2000).

discounted utility function is given by

$$U_t^h = \ln c_t^{h,t} + \frac{\ln c_{t+1}^{h,t}}{1+\rho}, \tag{1}$$

where $\rho > 0$ is the discount rate.

The period-specific budget constraints, which depend on the sector of employment in adulthood, are given by

$$c_t^{U,t} + s_t^U = w_t^U, \tag{2}$$

$$c_t^{S,t} + s_t^S = (1-\varepsilon)w_t^S, \tag{3}$$

$$c_{t+1}^{h,t} = (1+r_{t+1})s_t^h, \tag{4}$$

where $h = U, S$, s_t^h is the savings rate, and $1 + r_{t+1}$ the rate of return on holding (physical) assets between periods t and $t+1$.

Each individual knows his (her) own ability level a, as do all the firms that might potentially hire him (her). To avoid corner solutions, we will assume that individuals with ability $a \in (0, a^L)$ never choose to undergo training. An adult with ability $a \in (a^L, 1)$ can enter the labor force at t as an unskilled worker and earn the wage w_t^U, which is independent of the worker's ability. Alternatively, the individual may choose to spend first a fraction of time ε in training (or higher education), incur a cost tc_t, and enter the labor force for the remainder of the period as a skilled worker, earning the wage w_t^S. During training, workers earn no income. Thus, the opportunity cost of becoming skilled is equal to the foregone unskilled wage.

It is optimal for an individual with ability $a \in (a^L, 1)$ to train and become skilled if and only if[8]

$$(1-\varepsilon)w_t^S - tc_t \geq w_t^U. \tag{5}$$

The training cost is taken to be proportional to the wage that skilled workers earn once training is completed and they become employed, so that $tc_t = \mu w_t^S / a$, with $\mu \in (0, 1)$. Thus, more able individuals learn better and therefore incur a lower training cost.[9]

[8] Equation (5) is assumed to hold as a strict inequality for the individual with the highest ability, that is, $a = 1$, otherwise no one would choose to acquire skills.

[9] In line with Eicher and García-Peñalosa (2001) for instance, the cost of education parameter μ could be assumed to vary inversely with the proportion of skilled workers in the economy, as a result of fixed costs or externalities.

Equation (5), holding as an equality, gives the threshold level of ability a_t^C such that all individuals with ability lower than $a_t^C \geq a^L$ choose to remain unskilled:

$$a_t^C = \mu(1 - \varepsilon - \frac{w_t^U}{w_t^S})^{-1} = \frac{\mu w_t^S}{(1-\varepsilon)w_t^S - w_t^U}, \tag{6}$$

This equation describes an increasing and convex relationship between the wage ratio w_t^U/w_t^S and a_t^C. It also shows that an increase in the time that must be spent in training, ε , the cost of training, μ, or in the relative wage of unskilled labor, raises the fraction of the population that chooses to remain unskilled.

The productivity of unskilled workers, independently of their abilities, is constant and normalized to unity. Given (6), the (effective) supply of unskilled labor, N_t^U, equals the number of individuals in the population who choose to remain unskilled:

$$N_t^U = N_t \int_0^{a_t^C} f(a)da = F(a_t^C)N_t = a_t^C N_t. \tag{7}$$

The *raw* supply of skilled labor, at any time t, is $N_t \int_{a_t^C}^1 f(a)da = (1 - a_t^C)N_t$. However, the average skill level of workers with ability $a \in (a_t^C, 1)$ who have undergone training equals $(a_t^C + 1)/2$; thus, the *effective* supply of skilled labor at time t, can be defined as

$$N_t^S = \frac{(1 + a_t^C)}{2}(1 - a_t^C)N_t,$$

or equivalently

$$N_t^S = \frac{1 - (a_t^C)^2}{2} N_t. \tag{8}$$

3.2 Final Good

The final good is produced by a continuum of unit mass competitive firms indexed by $i \in (0, 1)$. Production requires the use of unskilled labor, $N_t^{U,i}$, capital, K_t^i, and a Dixit-Stiglitz combination of a continuum of intermediate inputs, $x_{s,t}^i$, where $s \in (0, M_t)$.[10]

The production function of firm i takes the form

$$Y_t^i = (K_t^i)^\alpha (e_t N_t^{U,i})^\beta [\int_0^{M_t} (x_{s,t}^i)^\eta ds]^{(1-\alpha-\beta)/\eta}, \tag{9}$$

[10] The analysis could be extended to account for the fact that skilled labor is also used in the production of the final good. This would, however, significantly complicate the analysis without adding much insight.

where $\alpha, \beta, \eta \in (0,1)$, $\alpha + \beta < 1$, e_t is labor productivity, and $1/(1-\eta) > 1$ is (the absolute value of) the price elasticity of demand for each intermediate good. Constant returns prevail in all inputs.

Labor productivity depends on the (adjusted) capital-labor ratio, as a result of a learning-by-doing effect:

$$e_t = \frac{K_t^{\upsilon}}{N_t^U}, \tag{10}$$

where $\upsilon > 0$, $K_t = \int_0^1 K_t^i di$ is the aggregate capital stock and $N_t^U = \int_0^1 N_t^{U,i} di$ is total employment in manufacturing.

With the price of the final good normalized to unity, and assuming for simplicity full depreciation of capital, profits of manufacturing firm i, $\Pi_t^{Y,i}$, are given by

$$\Pi_t^{Y,i} = Y_t^i - \int_0^{M_t} p_t^s x_{s,t}^i ds - w_t^U N_t^{U,i} - r_t K_t^i,$$

where p_t^s is the price of intermediate good s and r_t the rental rate of capital.

Each producer maximizes profits subject to (9) with respect to private inputs, labor, capital, and quantities of all intermediate goods $x_{s,t}^i$, $\forall s$, taking factor prices and M_t as given. This yields

$$r_t = \alpha \frac{Y_t^i}{K_t^i}, \quad w_t^U = \beta \frac{Y_t^i}{N_{i,t}^U}, \tag{11}$$

$$x_{s,t}^i = (\frac{\gamma Z_t^i}{p_t^s})^{1/(1-\eta)}, \quad s = 1, ...M_t, \tag{12}$$

where $\gamma = 1 - \alpha - \beta$ and

$$Z_t^i = Y_t^i / \int_0^{M_t} (x_{s,t}^i)^{\eta} ds. \tag{13}$$

Each firm demands the same amount of each intermediate input. Equation (12) therefore implies that the aggregate demand for intermediate input s is

$$x_{s,t} = \int_0^1 x_{s,t}^i di = \int_0^1 (\frac{\gamma Z_t^i}{p_t^s})^{1/(1-\eta)} di. \tag{14}$$

Because all firms producing the final good are identical and their number is normalized to unity, $K_t^i = K_t$, $Z_t^i = Z_t$, $\forall i$, and the total demand for intermediate inputs is the same across firms, $x_t^i = x_t$, $\forall i$. Moreover, in a symmetric equilibrium, $x_{s,t}^i = x_t^i$, $\forall s$.

Thus, $\int_0^1 [\int_0^{M_t} (x_{s,t}^i)^\eta ds] di = M_t x_t^\eta$. Using these results, equations (9) and (10) imply that aggregate output of the final good is

$$Y_t = \int_0^1 Y_t^i di = K_t^{\alpha + \upsilon\beta} M_t^{\gamma/\eta} x_t^\gamma.$$

To ensure steady-state growth, we impose $\alpha + \upsilon\beta + \gamma/\eta = 1$. This condition is equivalent to an implicit restriction on the magnitude of the productivity effect of capital, υ. Note that it also implies that $\gamma < \eta$, a condition that is used later.

Under this condition,

$$Y_t = m_t^{\gamma/\eta} x_t^\gamma K_t, \tag{15}$$

where $m_t = M_t / K_t$ is the (disembodied) knowledge-capital ratio.

3.3 Intermediate Goods

Firms in the intermediate sector are monopolistically competitive. There is only one producer of each input s, and each of them must pay a fee (a patent) to use the blueprint for that input created by designers. Production of each unit of an intermediate good s requires a single unit of the final good; the marginal cost of producing s is thus one.

Once the fee involved in purchasing a patent has been paid, each intermediate good producer sets its price to maximize profits, $\Pi_{s,t}^I$, given the perceived demand function for its good (which determines marginal revenue), $x_{s,t}$:

$$\Pi_{s,t}^I = (p_t^s - 1) x_{s,t}. \tag{16}$$

Substituting (14) in this expression and imposing $Z_t^i = Z_t$, $\forall i$, yields

$$\Pi_{s,t}^I = (p_t^s - 1)(\frac{\gamma Z_t}{p_t^s})^{1/(1-\eta)}.$$

Maximizing this expression with respect to p_t^s, taking Z_t as given, yields the optimal price as

$$p_t^s = p_t = \eta^{-1}, \quad \forall s \tag{17}$$

which implies, using (14), that the optimal quantity of each intermediate input demanded by producers of the final good is

$$x_{s,t} = x_t = (\gamma\eta Z_t)^{1/(1-\eta)}. \quad \forall s \tag{18}$$

From the definition of Z_t^i in (13), in a symmetric equilibrium $Z_t = Y_t/M_t x_t^\eta$. Substituting this expression in (18) yields

$$x_t = \gamma\eta(\frac{Y_t}{M_t}). \tag{19}$$

Substituting (17) and (19) in (16) yields the maximum profit for an intermediate-input producer:

$$\Pi_t^I = (1-\eta)\gamma(\frac{Y_t}{M_t}). \tag{20}$$

which is the standard expression obtained in Romer-type innovation models.

For simplicity, we assume that intermediate-input producing firms last only one period, and that patents are auctioned off randomly to a new group of firms in each period. Thus, each producer of a new intermediate good holds a patent only for the period during which it is bought, implying monopoly profits during that period only; yet patents last forever.[11] By arbitrage, therefore, the patent price p_t^R is

$$p_t^R = \Pi_t^I. \tag{21}$$

3.4 Design Sector

The outcome of a successful activity is a design, or blueprint, for the production of a new intermediate good. Let $q_t \in (0,1)$ denote the probability of success of a design activity. In a symmetric equilibrium, q_t is independent across designers and is therefore the same for all projects. The (expected) flow of new designs is given by

$$M_{t+1} - M_t = q_t A_t \frac{(1-\varepsilon)N_t^S}{N_t}, \tag{22}$$

where A_t is a productivity factor, common to all firms engaged in design activities. In addition, as in Dinopoulos and Thompson (2000), we also account for a dilution effect, which captures the fact that creating new designs becomes more difficult as the size of the market, measured by the size of the population, N_t, grows.

In standard fashion, productivity itself is linearly related to the existing stock of

[11]See Agénor and Canuto (2012) for a more detailed discussion of this assumption.

designs, to capture a standing-on-shoulders effect:[12]

$$A_t = M_t. \tag{23}$$

Designers have no wealth and must turn to external finance to cover production costs. The outcome of a research activity, however, is private information: only the designer can directly observe whether an activity has been successful, whereas lenders must spend resources on acquiring that information. To do so requires recourse to a costly monitoring technology.

As discussed next, each designer borrows from a financial intermediary, at the gross interest rate R_t, to cover wage costs. The zero-profit condition implied by free entry is given by

$$p_t^R A_t = w_t^S R_t N_t, \tag{24}$$

which, given the assumption of limited liability (discussed next), does not depend directly on q_t.

3.5 Financial Intermediation

Financial intermediation takes place solely between designers and lenders, under a regime of uncollateralized lending and limited liability; in case of default, lenders cannot recover any of their funds and no penalty can be imposed on borrowers. There exists a large number of lenders who compete in the provision of financial services. Each lender has access to a source of funding at the gross rate R_0. There is no risk of bankruptcy because they hold a perfectly diversified portfolio of loan contracts. As noted earlier, designers have no funds of their own to invest in their projects and therefore have to obtain external financing. Because of the limited liability constraint, a potential problem of moral hazard naturally emerges.

The funds needed for each research project are provided by lenders who are endowed with a monitoring technology. As in Morales (2003), the monitoring technology allows lenders to increase the effort of the designer; the intensity with which the lender

[12] As in Agénor and Canuto (2012), it could be assumed that there are increasing returns to the diffusion of ideas, at least in a certain range. However, in the present case this would not add much to the main argument.

monitors the designer who borrowed from him (her) determines the additional effort that the former can force the latter to exert. We also assume that there is a one-to-one relationship between individual effort and the probability of success of the research project.[13] As a result, the monitoring services of the lenders play an important role in determining productivity (and thus the capacity to innovate) in the design sector.

Consider a research project that requires using one worker, at the wage w_t^S.[14] If successful, an event that occurs with probability q_t, the project yields a return p_t^R, the price of the patent that is eventually acquired. The designer obtains the funds from a lender and in exchange pays in case of success an amount $R_t w_t^S$, where $R_t > 1 + r_t$ is an interest factor, and (as a result of the limited liability constraint) nothing otherwise.[15] The expected profit of the designer is thus given by

$$\Pi_t^D = q_t(p_t^R - R_t w_t^S). \tag{25}$$

If the designer is not monitored at all, the level of effort he would exert, and thus the probability of success of the project, is q_m, which we take to be constant. This no-monitoring level of effort is implementable at no cost for the lender. However, if the lender wishes to impose a higher level of effort, he faces a monitoring cost $G()$ that is positively and linearly related to the amount lent, and increasing and convex in the difference between the desired level of effort and q_m:

$$G(q_t - q_m; w_t^S) = \frac{\chi(q_t - q_m)^2}{2} w_t^S, \tag{26}$$

where $\chi > 0$ will be interpreted in what follows as a measure of the intensity of monitoring costs per project or, equivalently, the degree of credit market imperfections. We assume for the moment that χ is constant, but as shown later, its endogeneity is crucial to determining the existence of multiple equilibria.

[13] Thus, although the probability of success does not depend directly on innate ability, it is conditional on effort, which can vary independently of ability. However, and crucially for the analysis, effort is observable by creditors.

[14] In principle, as noted earlier, each worker in the design sector works for only $1 - \varepsilon$ of his time; we abstract from this to avoid cluttering needlessly the expressions derived in this section.

[15] To avoid a corner solution, we assume that the optimal payment, $R_t w_t^S$, cannot exceed the designer's return, p_t^R.

By implication, the expected profit (per borrower) of the lender is given by

$$\Pi_t^L = q_t R_t w_t^S - \left\{ R_0 + \frac{\chi(q_t - q_m)^2}{2} \right\} w_t^S, \tag{27}$$

which shows that, for R_t given, an increase in the probability of success q_t has two conflicting effects on expected profits: on the one hand, it raises the (expected) payoff for the lender, but on the other it raises monitoring costs.

As noted earlier, lenders compete among themselves for the provision of loans. By choosing one of them, and thus how much monitoring is exerted on his activities, a designer essentially determines the probability of success of his project. However, for simplicity we assume that once the researcher chooses a lender to finance his project, he cannot renege on the terms of the contract and seek another source of finance.

The equilibrium in the credit market follows from a three-stage process.[16] In the first stage, lenders choose the level of monitoring services that they want to provide, taking as given the return on loans and under the assumption that the borrower is "locked" into the contract. This, equivalently, determines the probability of success of the projects that they choose to finance. In the second stage, each designer chooses a lender on the basis of the level of monitoring services offered. Once that choice is made, but not before, the designer is tied with the lender and cannot walk away from the contract. In the third and final stage, the equilibrium payment to be imposed on the designer in case of success (that is, the gross lending rate) is determined through a zero-profit condition.

In the first stage the lender sets the level of effort that he wants (or equivalently the probability of success), so as to maximize profits, taking as given the return on loans. Setting $d\Pi_t^L/dq_t = 0$ in (27) yields the first-order condition

$$R_t = \chi(q_t - q_m), \tag{28}$$

which simply equates the marginal benefit, R_t, to the marginal cost of monitoring, $\chi(q_t - q_m)$. Rearranging this equation gives the equilibrium probability of success as

$$q_t = q_m + \frac{R_t}{\chi}, \tag{29}$$

[16] In Morales (2003), the equilibrium of the credit market is also solved through a three-stage process, but this is done backward. In the present setting, there is no advantage in doing so because the model is solved differently.

which implies (assuming that the solution is admissible) that an increase in the return on loans raises the amount of monitoring that lenders find optimal to engage in. Note also that, for R_t given, the higher the degree of credit market imperfections (the higher χ is), the smaller the probability of success. Put differently, if the (marginal) cost of monitoring increases, lenders will do less of it, therefore reducing the likelihood of success.

Substituting (28) in (25) gives $\Pi_t^D = q_t[p_t^R - \chi(q_t - q_m)w_t^S]$; taking p_t^R and w_t^S as given, expected profits of the designer are increasing in q_t if χ is sufficiently low. In such conditions, the contract makes monitoring desirable for him as well, because it will reduce the lender's share in the project's return and increase the probability that the project succeeds. Consequently, as long as $d\Pi_t^D/dq_t > 0$, in the second stage designers will choose the lender that offers the highest level of monitoring services.

In the third stage, competition among lenders in the provision of monitoring services ensures that the equilibrium level of expected profits for each lender is zero. Put differently, the gross return on loans will be the highest value of R_t that implies zero profits for lenders, that is, from (27),

$$q_t R_t - R_0 - \frac{\chi(q_t - q_m)^2}{2} = 0,$$

which can be rearranged to give

$$R_t = \frac{R_0 + 0.5\chi(q_t - q_m)^2}{q_t}. \tag{30}$$

Combining (29) and (30), and using the implicit function theorem, it can be established that, under mild conditions, an increase in χ raises the interest rate on loans. From (24), a higher loan rate tends to reduce the skilled wage in the design sector, and therefore mitigates incentives to acquire skills. Thus, credit market imperfections, which limit access to finance, not only tend to reduce activity in the design sector directly (by making it more costly), they tend also to affect it indirectly—by reducing the supply of skilled individuals. In addition, an increase in χ has in general an ambiguous effect on the probability of success; on the one hand, it increases the return on loans and raises the amount of monitoring, but on the other, it increases the marginal cost of monitoring. In what follows we will assume that the second effect dominates, implying that an increase in the monitoring cost lowers the probability of success ($dq/d\chi < 0$).

To close the model requires that the capital stock in $t+1$ be equal to savings in period t:

$$K_{t+1} = s_t^U N_t^U + s_t^S N_t^S. \tag{31}$$

4 Equilibrium

In this economy an *equilibrium with imperfect competition* is a sequence of consumption and saving allocations $\{c_t^{h,t}, c_{t+1}^{h,t}, s_t^h\}_{t=0}^{\infty}$, for $h = U, S$, capital stock $\{K_t\}_{t=0}^{\infty}$, prices of production inputs $\{w_t^U, w_t^S, r_{t+1}\}_{t=0}^{\infty}$, prices and quantities of intermediate inputs $\{p_t^s, x_{s,t}\}_{t=0}^{\infty}$, $\forall s \in (0, M_t)$, existing varieties, $\{M_t\}_{t=0}^{\infty}$, such that, given initial stocks $K_0 > 0$, and $M_0 > 0$,

a) individuals working in manufacturing and the design sector maximize utility by choosing consumption subject to their intertemporal budget constraint, taking factor prices and the tax rate as given;

b) firms in the final good sector maximize profits by choosing labor, capital, and intermediate inputs, taking input prices as given;

c) intermediate input producers set prices so as to maximize profits, while internalizing the effect of their decisions on the perceived aggregate demand curve for their product;

d) producers in the design sector maximize profits by choosing labor, taking wages, patent prices, productivity, monitoring costs, and population, as given;

e) the equilibrium price of each blueprint extracts all profits made by the corresponding intermediate input producer;

f) zero profits hold in the credit market; and

g) all markets clear.

A *balanced growth equilibrium* is an equilibrium with imperfect competition in which

a) $\{c_t^{h,t}, c_{t+1}^{h,t}, s_t^h\}_{t=0}^{\infty}$, for $h = U, S$, and K_t, Y_t, M_t, w_t^U, w_t^S, grow at the constant, endogenous rate $1 + g$, implying that the knowledge-capital ratio is also constant;

b) the net rate of return on capital r_{t+1} is constant;

c) the price of intermediate goods p_t and the patent price p_t^R are constant;

d) the probability of success in the design sector is constant; and

e) the threshold level of ability below which individuals choose to remain unskilled, a_t^C, and thus work in manufacturing, is constant. By implication, the fraction of the labor force employed in the design sector is also constant.

As shown earlier (equation (6)), the threshold level of ability a_t^C depends on the wage ratio, w_t^U/w_t^S. In the Appendix the wage ratio is shown to be given by

$$\frac{w_t^S}{w_t^U} = \frac{(1-\eta)\gamma}{\beta R_t} a_t^C. \tag{32}$$

Equating (6) and (32) yields

$$a_t^C = G(R_t) = \frac{1}{1-\varepsilon}\left\{\mu + \frac{\beta R_t}{(1-\eta)\gamma}\right\}, \tag{33}$$

which represents a linearly increasing relationship between a_t^C and R_t. Thus, a higher cost of loans (or, equivalently, a lower probability of success) raises the proportion of unskilled workers.

Now, let R^C be the value of the interest rate for which $a_t^C = a^L$, that is, all individuals with ability above a^L have chosen to engage in higher education and work in the design sector. From (33) this value is

$$R^C = (1-\eta)\gamma[\frac{(1-\varepsilon)a^L - \mu}{\beta}], \tag{34}$$

so that

$$a_t^C = \begin{cases} G(R_t) & \text{if } R_t \geq R^C \\ a^L & \text{if } R_t < R^C \end{cases}, \tag{35}$$

with $G' > 0$. Combining (29) and (30), as noted earlier, yields a solution that relates R_t positively to χ. The interest rate is thus constant as long as χ itself is constant.

The Appendix also shows that the fundamental dynamic equation of the system is

$$m_{t+1} = \Phi(m_t) = \frac{\Lambda^{-1}\{1 + q(1-\varepsilon)0.5[1 - G(R)^2]\}}{\sigma\{\beta + \Omega R^{-1}[1 - G(R)^2]\}} m_t^{(1-\gamma\eta^{-1})/(1-\gamma)}, \tag{36}$$

where $\sigma = 1/(2+\rho)$ is the marginal propensity to save, $\Lambda = (\gamma\eta)^{\gamma/(1-\gamma)}$, and $\Omega = 0.5(1-\varepsilon)(1-\eta)\gamma$.

The condition for stability is $|(1-\gamma\eta^{-1})/(1-\gamma)| < 1$, or equivalently $1-\gamma\eta^{-1} < 1-\gamma$. This condition boils down to $\eta < 1$, which is always satisfied. Thus, with both the interest rate on loans R and the probability of success q constant, there is a single equilibrium. If, in addition, $\eta > \gamma$, as is normally the case in practice, convergence occurs without oscillations.

The steady-state growth rate is given by

$$1+g = \Lambda m^{\gamma(\eta^{-1}-1)/(1-\gamma)}\sigma\{\beta + \Omega\frac{[1-G(R)^2]}{R}\}, \tag{37}$$

where m is the steady-state solution of (36), given by

$$m = \left\{\frac{\Lambda^{-1}\{1+q(1-\varepsilon)0.5[1-G(R)^2]\}}{\sigma\{\beta+\Omega R^{-1}[1-G(R)^2]\}}\right\}^{\varkappa}, \tag{38}$$

and $\varkappa = 1/[1-(1-\gamma\eta^{-1})/(1-\gamma)] > 0$.

Equations (37) and (38) show that the economy's steady-state growth rate depends on the cost of borrowing both directly, through its effect on activity in the design sector, and indirectly, through its impact on relative wages and labor supply. From (38), it can be shown that $dm/d\chi$ is in general ambiguous. On the one hand, an increase in the unit cost of monitoring raises the cost of loans ($dR/d\chi > 0$), which lowers wages, savings, and the capital stock. On the other, it leads to a reduction in effort, which lowers the probability of success ($dq/d\chi < 0$) and activity in the design sector. The first effect tends to lower the knowledge-capital ratio, whereas the second tends to increase it. This ambiguity exists even if there is no labor supply effect, that is, even if a^C is constant. In addition, however, the fall in the skilled wage raises the threshold value a^C and tends to reduce the share of skilled workers in the economy, thereby further reducing both activity in the design sector and aggregate savings and thus the capital stock. By implication, from (37), the impact of a higher χ on the steady-state growth rate is in general ambiguous, so that $d(1+g)/d\chi \lesseqgtr 0$. However, it can also be established that if $dm/d\chi < 0$, then $d(1+g)/d\chi < 0$ as well.[17] This result is useful in what follows.

[17] Suppose indeed that $\eta > \gamma$; thus, $(1-\gamma\eta^{-1})/(1-\gamma) > 0$. Given that $G' > 0$, $dR/d\chi > 0$, and $1-G(R)^2 > 0$, we have $\text{sg}[d\{[1-G(R)^2]/R\}/d\chi] = \text{sg}\{-2RG' - [1-G(R)^2]\} < 0$. Suppose also that $dm/d\chi < 0$; then, from (37), $d(1+g)/d\chi < 0$.

5 Multiple Equilibria

In the foregoing discussion, it was assumed that the intensity of monitoring costs per research project, as measured by χ, is constant. Suppose now instead that χ falls with the number of successful projects, scaled by the size of the economy (as measured by the capital stock), so that $\chi_t = \chi(m_t)$, with $\chi' < 0$. In addition, suppose that this relationship is concave ($\chi'' > 0$) and holds only for $\chi \in (\chi_m, \chi_M)$, where $\chi_m > 0$ and $\chi_M > \chi_m$. Intuitively, lenders learn from financing successful projects and this allows them to reduce monitoring costs—but at a decreasing rate and only up to a certain point. A possible reason for this negative relationship is that, in the tradition of Schumpeter (1961), by evaluating profitable (and eventually successful) projects, financial intermediaries help to lower information costs—thereby reducing, at least initially, the cost of screening and monitoring future borrowers. Alternatively, as in Blackburn and Hung (1998) and Harrison et al. (1999) for instance, an increase in the number of (successful) projects induces more lenders to enter the market; in turn, higher entry reduces the average distance between banks and borrowers, promotes regional specialization, and reduces the cost of screening and monitoring—again, at least in a first stage.

A specification that captures these assumptions is

$$\chi_t = \max(\chi_M - Am_t^{\upsilon}, \chi_m), \tag{39}$$

where $A > 0$ and $\upsilon \in (0, 1)$. Thus, unit monitoring costs fall continuously from χ_M as m_t increases and remain constant at χ_m once m_t reaches the critical value

$$m_H = (\frac{\chi_M - \chi_m}{A})^{1/\upsilon}. \tag{40}$$

As before, although lenders choose the level of monitoring effort, they take the monitoring cost per project (which depends on an *aggregate* quantity) as given. From equations (38) and (39), the steady-state knowledge-capital ratio m depends again on the monitoring cost parameter, through its direct effect on the cost of loans and the probability of success, R and q, from (29) and (30). However, in contrast to the case considered previously, χ_m the endogeneity of χ means that multiple equilibria may occur.

This possibility is illustrated in Figure 1, in m-χ space. Curve MM corresponds to the steady-state solution (38), and CC, which is shown in red for convenience, corresponds to equation (39). The slope of MM depends on the sign of $dm/d\chi$, which (as shown earlier) is in general ambiguous. If MM is positively sloped, multiple equilibria cannot occur. However, if it is negatively sloped multiple equilibria may emerge, depending on where the curves intersect. Figure 2 illustrates the case where MM is decreasing and concave. In Panel A, MM and CC intersect only once; there is a single equilibrium, corresponding to the point of tangency of the two curves. In Panel B, the curves intersect twice, at E and E'. For stability, curve MM must cut curve CC from above; this is always the case, for instance, when $\upsilon = 0$, in which case CC is a flat curve. Thus, point E is an unstable equilibrium, whereas point E' is stable. However, because E is unstable, if the economy starts away from it, it cannot converge to it. To the left of point m_E (the value of m corresponding to the equilibrium point E), a degenerate solution with an ever-increasing unit monitoring cost would obtain, whereas to the right of m_E the economy would always converge to the stable equilibrium. But at most, only two equilibria may exist.[18]

Figure 2 considers the case where MM is again decreasing but convex. Based on numerical simulations, this appears to be the most likely case.[19] Results similar to those obtained previously can again be derived, depending on the degree of convexity. In Panel A, there is a single equilibrium, whereas in Panel B, there are two equilibria, E and E'. As in Figure 1, point E is unstable whereas point E' is stable. However, it is now also possible to obtain three equilibria, as shown in Panel C, where MM and CC intersect three times. In that case, both E' and E'' are stable, whereas E

[18]Because χ_t is monotonically decreasing in m_t, the only case where a single equilibrium exists is the case depicted in Panel A. Note also that if MM could take a more complicated concave-convex-concave shape, then three equilibria could emerge. However, numerical experiments, as discussed later, suggest that this is a rather unlikely scenario.

[19]Initial simulations were conducted with time allocated to schooling $\varepsilon = 0.15$, a training cost $\mu = 0.05$ of the skilled wage, a propensity to save $\sigma = 0.12$, an elasticity of output with respect to capital $\alpha = 0.3$, an elasticity of output with respect to unskilled labor $\beta = 0.6$ (implying therefore an elasticity of output with respect to intermediate inputs of $\gamma = 0.1$), an elasticity of substitution between intermediate inputs $\eta = 0.6$, an autonomous probability of project success $q_m = 0.1$, and a unit monitoring cost initially at $\chi = 4.0$. Parameter values for α and β for instance are fairly standard, whereas the value of ε represents about 4 years of college if adulthood corresponds to 25 years. Subsequent experiments with a number of different values did not alter the results.

is unstable. The equilibrium at point E'', which is characterized by low steady-state activity in the design sector (low m) and high unit monitoring costs (high χ), and therefore low steady-state growth, corresponds to what we may call a middle-income trap. If the economy starts with a value of m located below m_E (the knowledge-capital ratio corresponding again to the unstable equilibrium) it will always converge to the trap and will remain stuck there when it reaches it.

What is the role of public policy in this setting? Suppose that the initial position of the economy is at point E'', which corresponds to a middle-income trap with high monitoring costs and a low knowledge-capital ratio. Suppose also that the government can implement a policy such as the creation of credit bureaus, which help to collect, analyze, and disseminate information about borrowers to potential lenders (what Laeven et al. (2013) refer to as *financial innovation*), thereby enhancing the screening and monitoring ability of financial intermediaries, and that the policy translates into a reduction in the threshold value χ_m in (39) and an increase in A. This, in turn, leads to a downward shift and clockwise tilt in CC (which therefore becomes steeper) as shown by the dotted curve in Panel D in Figure 2.[20] As long as $\chi > \chi_m$, the intensity of monitoring costs falls now at a faster rate with increases in m, and eventually settles at a lower level than before.

Moreover, starting at point E'', the shift in CC may be large enough for the new point of intersection with MM to be at Point B, where only a unique equilibrium remains, with a lower χ and a higher m. The policy shift will therefore induce on impact a downward vertical movement from E'' to a point on the new CC curve. From there, the economy will evolve gradually toward Point B, with a transition process characterized by increases in the knowledge-capital ratio and further reductions in unit monitoring costs.[21] The new equilibrium is characterized also by a larger share of skilled workers in the population, higher growth, and higher productivity in the design sector. Put differently, a forceful policy that makes it easier for innovators to

[20] As can be inferred from (40), a higher A tends to lower the threshold m_H, whereas a lower χ_m tends to increase it. The figure assumes that the net effect is a reduction in m_H. The main point of the analysis would also hold if instead m_H were to increase or to remain constant.

[21] Visual inspection of Panel D also suggests that with no change in the slope parameter A and a drop only in χ_m, the downward-sloping portion of CC could also shift in such a way as to achieve a single equilibrium.

secure financing for their projects may allow a country to escape from the middle-income trap, by putting its economy on a path that will eventually lead to a high-skill, high-innovation, and high-growth equilibrium.

6 Policy Implications

As noted in the introduction, a number of observers have argued that financial market imperfections, especially those associated with information asymmetries and transaction costs, are likely to be especially binding on talented individuals and small enterprises that lack collateral, credit histories, and connections. Indeed, it may be more difficult for small and newer firms, compared to larger and more established firms, to either raise outside finance (due to more severe problems of information asymmetries) or secure internal funds for the financing of innovation projects. As pointed out by the Inter-American Development Bank (2010) for instance, lack of finance—in addition to small domestic markets, and a shortage of trained personnel—is one of the key obstacles to innovation in Latin America. At the same time, although a country like Korea has succeeded—mainly because the R&D activities of its largest and most competitive conglomerates were financed internally or through captive funds—in becoming an innovation-based economy without highly developed venture capital markets, arguably it could have performed even better if its small and medium-size innovative firms had not faced severe financial constraints.

The foregoing analysis contributes to this debate in an important way. It suggests that access (or lack thereof) to finance may constrain growth not only by increasing the cost of monitoring innovation activities, as emphasized in other contributions such as Blackburn and Hung (1998), Morales (2003), Aghion et al. (2005), and Aghion and Howitt (2009), but also by indirectly altering incentives to acquire skills. This matters because the degree to which firms innovate and the distribution of skills among workers (which conditions the development of innovation activities) are jointly determined; lack of skills and poor access to finance are interrelated.[22] In addition, credit market imper-

[22] Attitude toward risk matters as well; to turn a promising idea into a new firm, researchers must also face the right incentives to give up safe employment for a risky entrepreneurial career.

fections may lead to the emergence of multiple equilibria, one of them corresponding to a middle-income trap. Yet, at the same time, public policy is not powerless—forceful measures aimed at mitigating the impact of these imperfections (or, more specifically, those aimed at reducing the unit cost of monitoring R&D projects) may allow a country to escape from that trap. As we define it here, the middle-income growth trap is consistent with the evidence on the high cost of financial intermediation in developing countries in general, and middle-income countries in particular (see for instance World Bank (2008)). It is also consistent with the fact that those among these countries that have experienced a significant and sustained slowdown in growth are often characterized by insufficient labor quality and limited R&D activity. But to a significant extent, the characteristics of the middle-income trap, as highlighted here, could equally apply to some high-income OCED countries where growth has remained anemic for significant periods of time, and promoting innovation remains a key policy challenge.

The broader policy lessons of our analysis are indeed consistent with the recent evidence (reviewed in Section 2) for both industrial and developing countries suggesting that financial constraints may be a key factor behind low innovation performance. If new entrants and startup firms are the most affected by the lack of finance, it may be important for governments to provide some form of direct assistance to these firms. Such measures include direct R&D funding, tax incentives for R&D, as well as support for innovation-related collaboration across firms and between universities/labs and firms (see OECD (2010), Lilischkis (2011), and LSE Growth Commission (2013)). Ensuring access to more funding sources may lead to more intensive innovation, more successful R&D projects which, in turn, may result in lower unit monitoring costs, thereby helping to further promote financial intermediation, innovation, and economic growth.[23] However, our analysis also suggests that, rather than providing direct subsidies, an alternative policy would be to implement measures that are aimed directly at mitigating asymmetric information problems and reducing unit monitoring costs, such

[23] The fact that in practice the importance of financial constraints may vary with firm characteristics points also to another conclusion: for any innovation policy program to be effective it is vital not to rely on uniform R&D and innovation support measures, but to provide programs that support different firms in different ways. Policies aimed especially at the most constrained firms are likely to yield the strongest benefits.

as for instance the creation of credit bureaus or registries that help to collect, analyze, and disseminate information about potential borrowers to lenders. The evidence suggests, for instance, that more effective credit information sharing is associated with greater availability and lower cost of bank loans to firms (World Bank (2014, Chapter 3)). Such a policy may actually be more effective in middle-income countries, given a weak institutional environment and the practical difficulties that may arise in selecting research projects whose outcomes are inherently uncertain.

Our analysis also points out that improved access to finance for innovative firms has side benefits—it may improve incentives to acquire skills, and therefore indirectly help to promote innovative research. At the same time, however, it is important to realize that in practice a strategy of promoting the financial sector across the board may not yield only benefits. The reason is that it could lead to a misallocation of talent, as discussed elsewhere in the literature (see, for instance, Ang (2011) and Agénor and Canuto (2012)). Indeed, if the expansion of the financial sector, by offering higher earnings and rewards, draws too many talented individuals, it could hamper in the long run the development of the innovation sector. Thus, rather than promoting finance in general, what is needed is a well-targeted policy aimed at making it easier for innovative firms to secure adequate funding for their activity.

7 Concluding Remarks

The purpose of this paper was to study interactions between access (or lack thereof) to finance, product innovation, and labor supply in a growing economy. To do so we developed an overlapping generations model of horizontal innovation in the tradition of Romer (1990), with an endogenous distribution of skills, credit market imperfections, and engaging in research activity involves borrowing from financial intermediaries. In the basic model, financial intermediaries provide uncollateralized loans to researchers in the design sector to finance wages, and monitor borrowers at a cost that depends solely on the amount lent and the level of effort required from researchers. The model also assumes that there is a one-to-one relationship between the level of effort and the probability of success of a research project. The model was subsequently extended to account for the possibility that the intensity of monitoring costs may fall, at least initially, with the number of successful projects. This reduction in costs may occur because the expertise acquired in evaluating profitable (and eventually successful) projects tends to reduce up to some extent the cost of screening and monitoring future borrowers.

The key result of our analysis is that, in line with other contributions in the literature, high intermediation costs may adversely affect innovation activity and the rate of economic growth in the long run. In addition, if the cost of borrowing is high, wages in the design sector will be relatively low. As a result, too few individuals may choose to invest in skills and engage in design activities. Thus, lack of access to finance not only exerts a direct, adverse effect on innovation activity (by constraining the number of research projects that are implemented), but also an indirect adverse effect as well. Moreover, if the intensity of monitoring costs depends on the number of research projects that have received financing (as a result of an information externality for instance), multiple equilibria may emerge, one of which characterized as a middle-income trap—a phenomenon that has been well documented in the recent literature on developing countries, where (except for a few exceptions) the cost of financial intermediation remains high, the quality of the labor force is weak, and R&D activity limited. The analysis also showed that an aggressive policy aimed at alleviating credit market imperfections and promoting access to finance by innovators may allow a country to move away from such a trap and lead to an equilibrium characterized by a high share of skilled workers in the population, high growth, and high productivity in design sectors. Thus, this policy benefits innovation and growth not only directly but also indirectly, by inducing more individuals to acquire an advanced education.

The main focus of our analysis has been on middle-income countries and on providing a rationale for the growth trap that seems to characterize the experience of many of these countries. In doing so we argued that accounting for the labor market distortions induced by inadequate access to finance is particularly important to understand the interactions between financial intermediation, innovation, and growth. In these countries, the supply of highly-qualified labor remains relatively limited, creating therefore another constraint on innovation activity. By contrast, in developed countries the issue may be less about the *quantity* of highly-skilled workers and more about the *allocation* of talent and the provision of adequate incentives to engage in risky entrepreneurial activities. Nevertheless, our analysis also has some relevance for industrial countries, where promoting growth and innovation remain key policy challenges. Indeed, as indicated in our review of the empirical evidence, in many of these countries access to finance remains an equally important constraint on the innovation activity of small and medium-sized firms—and may therefore be a source of a slow-growth equilibrium that bears some of the same characteristics as the middle-income trap that we characterize in our analysis. In such conditions, a sufficiently ambitious policy aimed at promoting access to finance is also essential to escape from a low-growth equilibrium and promote innovation growth.

The broad policy implications of our analysis are thus in line with a number of recent academic and policy contributions for both high- and middle-income countries (see Section 2, OECD (2010), and LSE Growth Commission (2013)), which have argued that lack of access to external finance may hamper the development of innovative firms. Because larger firms tend to be less constrained in their operation and growth by their ability to obtain external finance—a possible reflection of their ability to pledge collateral—promoting innovation requires a particular focus on improving access to finance for small and medium firms (Beck et al. (2005), World Bank (2008, 2012), and Dinh and Clarke (2012)). Indeed, in many countries a disproportionate share of innovative research continues to be conducted by this type of firms and organization theory suggests several reasons as to why this may be so (see Holmstrom (1989)). However, our analysis does not provide support for the use of direct subsidies to R&D firms, especially in the context of developing countries where targeting may be particularly difficult due to a weak institutional environment.[24] Rather, measures aimed at reducing the cost of collecting, processing, and disseminating information about potential borrowers may prove more effective in some of these countries.

Finally, although we did not introduce explicitly capital markets other than credit in our model, our analysis suggests that there may be a greater role for private finance

[24] As noted in the Introduction, Morales (2003) offers another argument that suggests that a subsidy to financial intermediation may be more effective than a direct subsidy to R&D activity.

to play in developing countries. Credit bureaus designed to share information about potential borrowers can be, and have been in the past, created by private agents—although free-rider problems and weak institutions may make government intervention necessary during an initial stage. More generally, while in many industrial countries there exists a private sector venture capital industry that provides financing for new and young innovative firms, this is not the case in most developing countries. In these countries, regulatory reform of financial markets should focus on the financing of innovative start-ups through venture capital markets, the securitization of innovation-related assets (namely, intellectual property rights) and the provision of appropriate incentives for risk-taking.

References

Acharya, Viral V., and Krishnamurthy V. Subramanian, "Bankruptcy Codes and Innovation," *Review of Financial Studies*, 22 (December 2009), 4949-88.

Agénor, Pierre-Richard, and Otaviano Canuto, "Middle-Income Growth Traps," Policy Research Working Paper No. 6210, World Bank (September 2012).

Aghion, Philippe, and Peter Howitt, *The Economics of Growth*, MIT Press (Cambridge, Mass.: 2009).

Aghion, Philippe, Peter Howitt, and David Mayer-Foulkes, "The Effect of Financial Development on Convergence: Theory and Evidence," *Quarterly Journal of Economics*, 120 (January 2005), 173-222.

Ang, James B., "Research, Technological Change and Financial Liberalization in South Korea," *Journal of Macroeconomics*, 32 (March 2010), 457-68.

——, "Financial Development, Liberalization and Technological Deepening," *European Economic Review*, 55 (June 2011), 688-701.

Aiyar, Shekhar, Romain Duval, Damien Puy, Yiqun Wu, and Longmei Zhang, "Growth Slowdowns and the Middle-Income Trap," Working Paper No. 13/71, International Monetary Fund (March 2013).

Ayyagari, Meghana, Asli Demirgüç-Kunt, and Vojislav Maksimovic, "Firm Innovation in Emerging Markets: The Roles of Governance and Finance," *Journal of Financial and Quantitative Analysis*, 46 (September 2011), 1545-80.

Beck, Thorsten, Asli Demirguc-Kunt, and Vojislav Maksimovic, "Financial and Legal Constraints to Firm Growth: Does Firm Size Matter?," *Journal of Finance*, 60 (March 2005), 137-77.

Blackburn, Keith, and Victor T. Hung, "A Theory of Growth, Financial Development and Trade," *Economica*, 65 (February 1998), 107-24.

Brown, James R., Gustav Martinsson, and Bruce C. Petersen, "Do Financing Constraints Matter for R&D?," *European Economic Review*, 56 (November 2012), 1512-29.

De la Fuente, Angel, and José M. Marín, "Innovation, Bank Monitoring, and Endogenous Financial Development," *Journal of Monetary Economics*, 38 (October 1996), 269-301.

De Mel, Suresh, David McKenzie, and Christopher Woodruff, "Innovative Firms or Innovative Owners? Determinants of Innovation in Micro, Small, and Medium Enterprises," Policy Research Working Paper No. 4934, World Bank (May 2009).

Dinh, Hinh T., and George R. G. Clarke, eds., *Performance of Manufacturing Firms in Africa: An Empirical Analysis*, World Bank (Washington DC: 2012).

Dinopoulos, Elias, and Peter Thompson, "Endogenous Growth in a Cross-Section of Countries," *Journal of International Economics*, 51 (August 2000), 335-62.

Efthyvoulou, Georgios, and Priit Vahter, "Financial Constraints and Innovation Performance: Are all Firms Similar?," unpublished, University of Birmingham (August 2012).

Eicher, Theo, and Cecilia García-Peñalosa, "Inequality and Growth: The Dual Role of Human Capital in Development," *Journal of Development Economics*, 66 (October 2001), 173-97.

Eichengreen, Barry, Donghyun Park, and Kwanho Shin, "When Fast Economies Slow Down: International Evidence and Implications for China," *Asian Economic Papers*, 11 (March 2012), 42-87.

——, "Growth Slowdowns Redux: New Evidence on the Middle-Income Trap," Working Paper No. 18673, National Bureau of Economic Research (January 2013).

Faria, Ana Paula, and Natália Barbosa, "Does Venture Capital really Foster Innovation?," *Economics Letters*, 122 (February 2014), 129-31.

Felipe, Jesus, Arnelyn Abdon, and Utsav Kumar, "Tracking the Middle-Income Trap: What is it, who is in it, and why?," Working Paper No. 715, Levy Economics Institute (April 2012).

Galetovic, Alexander, "Specialization, Intermediation, and Growth," *Journal of Monetary Economics*, 38 (December 1996), 549-59.

Galor, Oded, and Omer Moav, "Ability Biased Technological Transition, Wage Inequality and Growth," *Quarterly Journal of Economics*, 115 (May 2000), 469-98.

Gorodnichenko, Yuriy, and Monika Schnitzer, "Financial Constraints and Innovation: Why Poor Countries don't Catch up," *Journal of European Economic Association*, 11 (October 2013), 1115-52.

Hall, Bronwyn H., and Lerner Josh, "The Financing of R&D and Innovation," in *Handbook of the Economics of Innovation*, ed. by Bronwyn H. Hall and N. Rosenberg, North Holland (Amsterdam: 2010).

Harrison, Paul, Oren Sussman, and Joseph Zeira, "Finance and Growth: Theory and New Evidence," Discussion Paper No. 1999-35, Federal Reserve Board (July 1999).

Hirukawa, Masayuki, and Masako Ueda, "Venture Capital and Innovation: Which is First?," *Pacific Economic Review*, 16 (December 2011), 421-65.

Holmstrom, Bengt, "Agency Costs and Innovation," *Journal of Economic Behavior and Organization*, 12 (December 1989), 305-27.

Hottenrott, Hanna, and Bettina Peters, "Innovative Capability and Financing Constraints for Innovation: More Money, more Innovation?," *Review of Economics and Statistics*, 94 (November 2012), 1126-42.

Hsu, Po-Hsuan, Xuan Tian, Yan Xu, "Financial Development and Innovation: Cross-Country Evidence," *Journal of Financial Economics*, 112 (April 2014), 116-35.

Ilyina, Anna, and Roberto Samaniego, "Technology and Financial Development," *Journal of Money, Credit and Banking*, 43 (August 2011), 899-921.

Im, Fernando G., and David Rosenblatt, "Middle-Income Traps: A Conceptual and Empirical Survey," Policy Research Working Paper No. 6594, World Bank (September 2013).

Inter-American Development Bank, "The Importance of Ideas: Innovation and Productivity in Latin America," in *The Age of Productivity*, ed. by Carmen Pagés, Inter-American Development Bank (Washington DC: 2010).

International Finance Corporation, *Assessing Private Sector Contributions to Job Creation*, IFC publications (Washington DC: 2013).

Jimenez, Emmanuel, Vy Nguyen, and Harry A. Patrinos, "Stuck in the Middle? Human Capital Development and Economic Growth in Malaysia and Thailand," Policy

Research Working Paper No. 6283, World Bank (November 2012).
Keuschnigg, Christian, “Optimal Public Policy for Venture Capital Backed Innovation,” Discussion Paper No. 2003-09, University of St. Gallen (March 2003).
Laeven, Luc, Ross Levine, and Stelios Michalopoulos, “Financial Innovation and Endogenous Growth,” unpublished, Brown University (June 2013).
LSE Growth Commission, *Investing for Prosperity: Skills, Infrastructure and Innovation*, London School of Economics (London: 2013).
Maskus, Keith E., Rebecca Neumann, and Tobias Seidel, “How National and International Financial Development Affect Industrial R&D,” *European Economic Review*, 56 (January 2012), 72-83.
Lilischkis, Stefan, “Policies in Support of High-Growth Innovative SMEs,” INNO-Grips Policy Brief No. 2, European Commission (June 2011).
Morales, María F., “Financial Intermediation in a Model of Growth through Creative Destruction,” *Macroeconomic Dynamics*, 7 (June 2003), 363-93.
OECD, *The OECD Innovation Strategy: Getting a Head Start on Tomorrow*, OECD (Paris: 2010).
Popov, Alexander, and Peter Roosenboom, “Venture Capital and Industrial Innovation: Evidence from Europe,” *Economic Policy*, 27 (July 2012), 447-82.
Romer, Paul M., “Endogenous Technological Change,” *Journal of Political Economy*, 98 (October 1990), s71-s102.
Savignac, Frédérique, “Impact of Financial Constraints on Innovation: What can be Learned from a Direct Measure?,” *Economics of Innovation and New Technology*, 17 (August 2008), 553-69.
Schumpeter, Joseph A., *The Theory of Economic Development*, Oxford University Press (New York: 1961).
Sharpe, Samantha, “Risk Capital and Innovation: Venture Capital Literature Review,” unpublished, University of Cambridge (August 2009).
Silva, Filipe, and Carlos Carreira, “Do Financial Constraints Threaten the Innovation Process? Evidence from Portuguese Firms,” *Economics of Innovation and New Technology*, 21 (November 2012), 701-36.
World Bank, *Finance for All: Policies and Pitfalls in Expanding Access*, Policy Research Report, World Bank (Washington DC: 2008).
——, *Jobs*, World Development Report, World Bank (Washington DC: 2012).
——, *Financial Inclusion*, Global Financial Development Report, World Bank (Washington DC: 2014).

Figure 1
Equilibrium with Endogenous Unit Monitoring Costs:
Decreasing and Concave *MM*

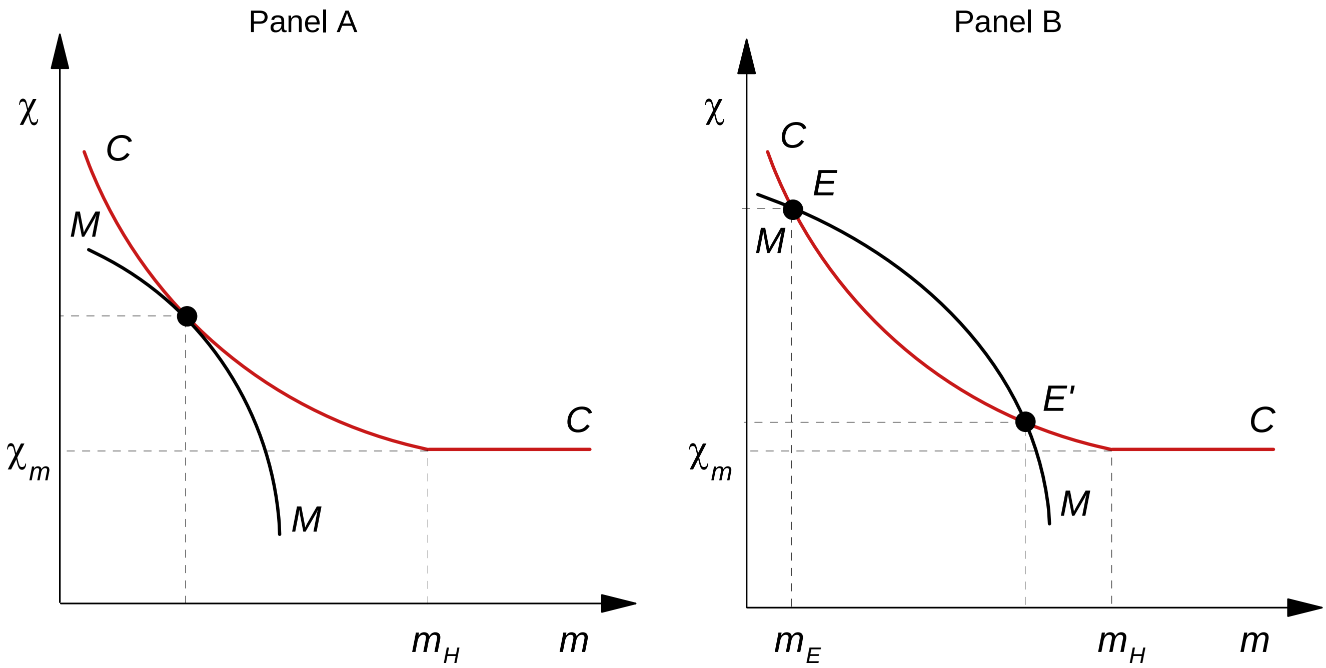

Figure 2
Equilibrium and the Role of Public Policy:
Decreasing and Convex *MM*