Innovation, Trade, and Finance*

Peter Egger Christian Keuschnigg

February 10, 2012

Abstract

This paper proposes a model where heterogeneous firms choose whether to undertake R&D or not. Innovative firms are more productive, have larger investment opportunities and lower own funds for tangible continuation investments than non-innovating firms. As a result, they are financially constrained while non-innovative firms are not. The efficiency of the financial sector and a country's institutional quality relating to corporate finance determine the share of R&D intensive firms and their comparative advantage in producing innovative goods. We illustrate how tariffs, R&D subsidies, and financial sector development improve access to external finance in distinct ways, support the expansion of innovative industries, and boost national welfare. International welfare spillovers depend on the interaction between terms of trade effects and financial frictions and may be positive or negative, depending on foreign countries' trade position.

JEL classification: F11, G32, L26, O38
Keywords: Innovation, financial development, R&D subsidies, tariffs.

Egger: ETH Zuerich, KOF, Weinbergstrasse 35, CH-8092 Zurich, Switzerland. Email: Egger@kof.ethz.ch
Keuschnigg: University of St. Gallen, FGN-HSG, Varnbuelstrasse 19, CH-9000 St.Gallen, Switzerland. Email: Christian.Keuschnigg@unisg.ch

*We are grateful to comments on earlier versions of the manuscript at presentations at the CEPR workshop on *Corporate Finance and Economic Performance* in St. Gallen, the annual meeting of the German Economic Association in Kiel and of the European Economic Association in Oslo, the CESifo Area Conference on Global Economy in Munich, the *GEP, ifo, Murphy Institute Conference on Finance and Trade* in Nottingham, the Kiel International Economics Meeting on *Globalization, Finance and Firm Dynamics* and at seminar presentations at University of St. Gallen, University of Cologne and the Institute for Advanced Studies in Vienna. In particular, we would like to thank Philippe Aghion, Pol Antràs, Simon Evenett, Thibault Fally and Holger Görg for helpful comments.

1 Introduction

Despite their large investment opportunities, innovative firms are more frequently finance constrained than less innovative ones due to credit rationing (see Brown, Ongena, Popov, and Yeşin, 2011). R&D intensive sectors are thus financially dependent in the sense of Rajan and Zingales (1998). This paper sheds light on the mechanisms determining (endogenous) financing constraints in the presence of firms' discrete R&D decisions and their consequences for tangible investment, comparative advantage, and trade. We assume that financing constraints root in a moral hazard problem in the relationship between entrepreneurs and outside investors as postulated in Holmstrom and Tirole (1997) or Tirole (2001, 2006). For external funding to be incentive compatible, entrepreneurs must keep a minimum stake which limits the share of income pledgeable to outside investors. Hence, the level of pledgeable income determines a firm's debt capacity, i.e., the level of external credit it can raise from banks and outside investors.

Unlike in other models of real effects of finance, we distinguish between passive, standard banks and active financial intermediaries who engage in monitoring of investment projects. Entities we have in mind with the latter are venture capitalists, specialized investment banks, 'Hausbanken', or other intermediaries engaged in relationship banking. Credit from active banks is thus not suitable to all firms. Costs of monitoring have to be matched by associated benefits. If standard banks are not willing to finance investment projects at the desired scale, there may be room for active banks to serve firms with high investment opportunities and to help them raising a larger amount of external funds. This entails a *certification function* of active intermediaries, which leads also standard banks to lend more to monitored (certified) entrepreneurs than they would in the absence of monitoring. Hence, monitoring is beneficial by incentivizing entrepreneurs, raising firms' debt capacity, and improving access to external credit. Altogether, this boosts firm value through the greater realization of profitable investment. If monitoring helps exploiting otherwise unused investment opportunities with high returns, credit from active banks becomes valuable to innovative firms in spite of being more expensive than credit from

standard bank financing.[1] We model and interpret financial sector development as a productivity improvement of active banks in performing monitoring. As a consequence, financial development relaxes financing constraints, encourages innovation, and raises tangible investments and the value of constrained (innovative) firms. In this way, financial development becomes a source of comparative advantage in innovative sectors. Such a framework allows for a deeper modeling of the sources of financial constraints and financial development relative to previous work.

We consider countries with two sectors: a non-innovative sector where firms display low productivity and are not finance constrained so that the Modigliani-Miller irrelevance theorem applies; and an innovative sector where firms are potentially constrained in their access to external finance. Innovative sector production is driven by entrepreneurial firms which are heterogeneous in their early stage survival probabilities. After entry, they decide whether or not to undertake a discrete R&D investment with two consequences: (i) R&D spending uses up own assets and (ii) creates higher productivity which results in better subsequent tangible investment opportunities and, hence, a larger optimal scale. These firms are the prototype of highly productive growth companies with few own assets and large tangible investment opportunities. They are financially dependent and require a high amount of external funds. How many of the entrepreneurial firms adopt an aggressive R&D strategy, how much continuation investment they undertake, and to which extent they are constrained is endogenously determined in our model. Hence, the R&D decision determines the extensive and intensive margins of financial constraints and capital investments in the innovative sector.

[1] This notion is consistent with at least two stylized facts: (i) innovative firms often require more sophisticated forms of finance (see Gompers and Lerner, 2001), and (ii) active financial intermediaries typically specialize in financing more innovative firms and help them grow larger. Sorensen (2007) shows that better investors match with better firms and also actively support them. Bottazzi et al. (2008) show that investor activism is human capital intensive and promotes firm performance by helping with fundraising and other managerial support. Venture capital accounts for a rather small part of total investment but is concentrated in the most innovative sectors. Kortum and Lerner (2000) found that venture capital is responsible for a disproportionately large share of industrial innovation in the U.S.

We utilize this framework to study consequences of three alternative policy instruments which address financial frictions in distinct ways for (small or large) open economies.[2] The key results are the following. First, in raising the domestic price and earnings per firm, *import tariffs* boost earnings and the debt capacity of constrained firms. Import protection thereby relaxes financing constraints, allows innovative firms with an excess rate of return to invest at a larger scale, and induces more firms to innovate. For this reason, when market frictions prevent full financing of highly profitable, tangible investments of innovative firms, a small level of tariff protection can raise domestic welfare. The latter is an argument in favor of protection which is related to ones brought forward in the context of infant industry protection in the absence of financial frictions (see Clemhout and Wan, 1970; and Mayer, 1984). A key argument was the existence of informational barriers which may prevent consumers to enter a contract with producers so that consumer experience was needed and, by protecting an infant industry, information costs were lowered.[3] In our model, gains from protection arise from informational barriers between producers and financial intermediaries (rather than consumers).[4]

Second, *R&D subsidies* boost innovation and lead to welfare gains, not because of knowledge spillovers which are excluded in our model,[5] but because they increase own funds which, in turn, renders innovating firms more successful in attracting external in-

[2]See Kletzer and Bardhan (1987) and Baldwin (1989) for early work on the impact of financial frictions in economies which are open to goods trade and Antràs and Caballero (2009) and Ju and Wei (2011) for considering financial frictions in economies which are open to goods trade and capital flows.

[3]The argument was taken with some scepticism (see Corden, 1974; Grossman and Horn, 1988). The debate between Mayer (1984) and Grossman and Horn (1988) illustrated that the desirability of protection depends on the nature and time structure of information asymmetries between consumers and producers.

[4]Notwithstanding, since protection entails a discriminatory treatment not only of domestic and foreign firms but also of innovative and non-innovative sector firms, other instruments as discussed in the paper will have less distorting effects and are preferable to protection of the innovative sector.

[5]R&D subsidies are discussed in the literature on endogenous growth as a means to reduce market failures associated with external economies. Grossman and Helpman (1991) discuss beneficial effects of R&D subsidies when R&D generates positive spillovers to consumers and succeeding innovators. In our context, R&D subsidies remove market failures related to limited access to external credit.

vestors.[6] Altogether, this allows them to more fully exploit profitable investment opportunities with an excess rate of return and renders R&D investments yet more profitable to entrepreneurs. Akin to and beyond protection, an R&D subsidization policy boosts national welfare and shifts comparative advantage towards the innovative sector.

Finally, we investigate the consequences of *financial sector development* in terms of improved monitoring productivity of active financial intermediaries. Since monitoring is useful only for financially constrained, innovative firms, those consequences are qualitatively similar to the ones of the other two instruments: financial sector development relaxes financing constraints in the innovative sector, raises firms' debt capacity, and boosts national welfare. The quality of the financial sector becomes a source of comparative advantage in the R&D intensive and financially dependent sector.

While all three policies reduce financial frictions in the innovative sector and yield welfare gains, their consequences on foreign welfare are not uniform and depend on the specific interaction of terms of trade effects and financial frictions. In general, policies which reduce the world price of innovative goods strongly hurt foreign exporters of that good, not only because of terms of trade losses, but also because lower prices tighten financing constraints. In foreign import countries, a lower price of innovative goods yields terms of trade gains which tend to offset the negative effects on financial frictions.

The novel contributions of the present paper compared to earlier work on the real effects of financial constraints in open economies are as follows. First, rather than treating financial constraints as an exogenous parameter, they emerge endogenously through a discrete innovation choice of heterogeneous firms and arise at the extensive and intensive margins of constrained tangible investment. They are driven by deep characteristics of the financial industry such as a co-existence of standard and active banks. The latter engage in monitoring and active oversight but are suitable only to constrained innovative firms. The tightness of financing constraints depends inter alia on structural parameters relating

[6] Unlike as in a frictionless Modigliani-Miller world, investment is sensitive to cash-flow and own assets in our setting with financial constraints.

to costs and effectiveness of monitoring. While active banking is more costly than standard banking, it brings about a certification effect for R&D intensive firms which helps them to raise additional standard credit and to better exploit highly profitable investment opportunities. In making innovative production more profitable, it also stimulates discrete, early-stage R&D and leads to a larger share of innovative firms, thereby raising average productivity and R&D intensity in the innovative sector. Monitoring leads to greater supply and, in turn, more demand for credit as a whole, from active as well as standard banks. A better monitoring technology reduces the costs of certification so that the demand for active banking, and the volume of credit transmitted through active banks, increases endogenously. Second, we analyze and compare three different policy instruments – tariff protection of the innovative sector, R&D subsidies, and financial development – with regard to their impact on financial constraints, national equilibrium, and the pattern of a country's trade. In doing so, we emphasize the importance of differences in financial development as captured by the monitoring technology parameters. Third, we provide a complete analysis of national and international welfare consequences of these policy alternatives for small and large countries and show how they depend on the interaction between terms of trade effects and financial frictions.

The paper proceeds as follows. The next section provides a literature review. Section 3 sets up the model, Section 4 analyzes equilibrium and comparative static effects of policy intervention in a small open economy, and Section 5 turns to policy effects in a large economy in world equilibrium. The concluding section summarizes the key insights.

2 Real Effects of Finance: Empirical Evidence

The main building blocks of our model – both with regard to the sources and the consequences of financial constraints – are well backed by empirical evidence. In what follows, we summarize findings of empirical work on the roots as well as the consequences of financial constraints. In a seminal paper, Rajan and Zingales (1998) show that, at the

macro level, poorly developed financial markets are one important reason for financing constraints which impair the growth of companies dependent on external finance. Similarly, access to external finance is more constrained in countries with poorly developed property rights (Beck, Demirgüç-Kunt, and Maksimovic, 2008). Moreover, work by Hoshi, Kashyap, and Scharfstein (1991), Schaller (1993), and Chirinko and Schaller (1995) points to information asymmetries between financial intermediaries and firms as a source of financing constraints: when firms have close ties to banks, the informational asymmetry is reduced, and they are more likely to obtain the required funding. There is evidence that such financing constraints are particularly severe for small firms (see Fisman and Love, 2003; Beck, Demirgüç-Kunt, and Maksimovic, 2005, 2008; Aghion, Fally, and Scarpetta, 2007). It appears that firm size matters for external credit even in developed countries with relatively developed financial markets.

In differentiating by firm size, Beck, Demirgüç-Kunt, and Maksimovic (2005) find that financing constraints are most relevant for small firms. As financial and institutional characteristics improve, constraints become less tight. Small firms catch up and benefit the most. These results are confirmed by Beck, Demirgüç-Kunt, and Maksimovic (2008) who focus on the importance of alternative sources of finance for small and large firms. Well developed property rights boost external financing in small firms more strongly than in large firms. The increase mainly results from easier access to bank credit. Other sources of finance are not able to compensate for lacking access to bank financing. The same finding is reported by Fisman and Love (2003) who study trade credit as an alternative funding source when financial markets are poorly developed. The importance of firm size for financial market access is already apparent when a firm is created (see Aghion, Fally, and Scarpetta, 2007). Financial development most strongly raises entry rates of smaller firms whereas entry of larger firms displays no or even a negative response. Even in advanced economies, there is scope to promote entry of small firms and their subsequent growth by improving institutions. Moreover, financial constraints are stronger for firms which can not offer much collateral to outside investors. This leads to an industry pattern in the intensity of financial constraints and suggests that innovative firms – with a low degree of

asset tangibility – are ceteris paribus more constrained (Himmelberg and Petersen, 1994; Guiso, 1998; Hall and Van Reenen, 2000; Ughetto, 2008, 2009; Bloom, Griffith and Van Reenen, 2002; Hall, 2002; Brown and Petersen, 2009; Hall and Lerner, 2009).

As a result of financing constraints, firms conduct less investments than they would otherwise. Unlike in a Modigliani-Miller world, this leads investments to depend on cash flow (see Hoshi, Kashyap, and Scharfstein, 1991; Fazzari and Petersen, 1993; Schaller, 1993; Calomiris and Hubbard, 1995; Chirinko and Schaller, 1995; Kaplan and Zingales, 1997; Carpenter and Petersen, 2002; Hubbard, 1998, provides a survey of such evidence). By influencing investment, financing constraints have been shown to influence a country's comparative advantage in terms of its sectoral trade structure by impairing production and (net-)exports of constrained sectors (cf. Beck, 2002, 2003; Svaleryd and Vlachos, 2005; Manova, 2008a; Gorodnichenko and Schnitzer, 2010). This research concludes that countries with better developed financial institutions have a comparative advantage in industries which rely more intensively on external finance, and financial market liberalization increases exports disproportionately more in financially vulnerable sectors where firms require more outside finance and have fewer assets serving as collateral. The results in Svaleryd and Vlachos (2005) indicate that differences in financial systems may be even more important for specialization patterns than differences in human capital.[7]

[7] Do and Levchenko (2007) argue that financial development is endogenous and present evidence that it depends on trade patterns. Demand for external funds might be influenced by trade patterns shifting towards financially dependent sectors. Beyond trade structure, financial constraints reduce the volume of trade by inducing exit of firms with below-average productivity (see Manova, 2008b). Recent work indicates that limited access to credit through weak investor protection reduces foreign direct investment and trade by multinational companies (see Chor, Foley, and Manova, 2008; Antràs, Desai and Foley, 2009), and alters the decision to deploy technology through foreign direct investment as opposed to arm's length technology transfers. The latter lies beyond the scope of this paper.

3 The Model

3.1 Overview

We develop a multicountry model of innovation, trade and finance, including two goods and two factors in each country. We first introduce the structure of the domestic economy, taking world prices as given. A Ricardian sector produces the *numéraire* good with a linear technology that transforms one unit of labor into one unit of output, and one unit of capital into $R > 1$ units of output. The Ricardian technology fixes deposit and wage rates. There are L workers without assets who have no managerial talent and can only work in the Ricardian sector, earning a competitive wage equal to unity. The innovative sector consists of heterogeneous firms, driven by entrepreneurs who make risky innovation and investment choices. The country hosts a unitary mass of wealthy, risk-neutral individuals endowed with assets A per capita. A *fixed* fraction E has entrepreneurial ability. The remaining part $1 - E$ does not and invests wealth in the deposit market paying a safe interest r ($R = 1 + r$). Entrepreneurs earn an expected surplus π_E on top of AR. Given an expected rent $\pi_E > 0$, all E agents with entrepreneurial ability indeed prefer investing in their own firm rather than in the capital market.

We think of a firm as an entrepreneur managing one project. Innovative sector production thus combines one unit of entrepreneurial labor and equipment I, using a strictly concave technology $\theta f(I)$ where productivity θ is determined by discrete innovation choice. Entrepreneurs first decide on R&D and subsequently choose the level of equipment investment. If successful, high R&D spending, $k > 0$, results in a high productivity level, $\theta > 1$. For convenience, we normalize low R&D cost to zero and low productivity to unity, i.e., $k = 0$ leads to $\theta = 1$. R&D is successful with probability q'. Conditional on surviving the R&D stage, investment succeeds with probability p and fails with probability $1 - p$. When the firm fails, it closes down, before any output is produced, either in the early R&D or the late investment stage. All assets are lost and income drops to zero.

Entrepreneurs are heterogeneous with respect to their innate ability to innovate, given

by a success probability $q' \in [0,1]$ of the R&D stage. This characteristic is drawn from the distribution $G(q) = \int_0^q g(q')\,dq'$. More able and innovative entrepreneurs have a higher chance of turning R&D into a success. At the beginning, all entrepreneurs start out with the same level of assets A. The timing of events is**:** (i) Given project type q', firms decide on R&D strategy j which requires a fixed investment $k_j \in \{0, (1-\sigma)k\}$, leaves residual assets $A_j = A - k_j$ and determines productivity θ_j. R&D cost may be reduced by a proportional subsidy σ. (ii) When surviving the early stage, firms choose investment I_j and apply for credit $I_j - A_j$, possibly from different sources. (iii) Given investment and the financial contract, entrepreneurs supply managerial effort and banks choose monitoring effort (if necessary). High effort results in a high success probability p. If financing is not incentive compatible, the success probability falls to $p_L < p$. (iv) Firms produce output and pay back external funds if investment is successful.

The returns to R&D accrue only if a firm survives the start-up period. Firms with sufficiently high survival chances $q' > q$ will adopt an aggressive innovation strategy and opt for a high R&D budget, see below. R&D drains own resources but creates large investment opportunities, making these firms financially dependent in the expansion stage. Firms with less potential choose a more conservative growth strategy and abstain from R&D, have undiminished own resources, are less productive, have few investment opportunities and, by assumption, will be financially unconstrained. Let the subindex $j = c$ refer to constrained, R&D intensive firms and $j = u$ to unconstrained firms with little (zero) R&D spending. Conditional on their innovation strategy, firms expect profits $\pi_c > \pi_u$ from subsequent investment. Ex ante, the expected profit of starting a firm is

$$\pi_E = \int_0^1 \left(\pi(q')\,q' - k_c(q')\,R\right) dG(q') = \int_0^q \pi_u q' dG(q') + \int_q^1 \left(\pi_c q' - k_c R\right) dG(q'). \quad (1)$$

Depending on prior R&D choice, firms differ in productivity and residual assets. To finance expansion investment, they need additional external funds. If necessary, a firm can obtain a part D_j^m of the required funds from active, monitoring banks (e.g., venture capital, investment banks, 'Hausbanken') and the remaining part $D_j = I_j - A_j - D_j^m$ from other, passive banks. The role of monitoring banks is to facilitate access to capital if

external funds are unavailable otherwise. At the end of period, if investment is successful, firms sell output $x_j = \theta_j f(I_j)$ in the innovative goods market at a relative price v, and undepreciated capital I_j adds to traditional sector output. A firm's expected profit π_j is divided between the entrepreneur and external investors, receiving π_j^e,

$$\pi_j^e = p\left[I_j + vx_j - (1+i)D_j - (1+i^m)D_j^m\right] - RA_j. \tag{2}$$

External investors receive $\pi_j^b = p(1+i)D_j - RD_j$ and $\pi_j^m = p(1+i^m)D_j^m - RD_j^m - cI_j$, respectively. Adding up all claims yields $\pi_j = p(I_j + vx_j) - cI_j - RI_j$. Active banks incur monitoring costs c per unit of investment, measured in terms of labor or numeraire output. We assume perfect competition in financial intermediation. Entrepreneurs thus extract the full surplus of the firm, $\pi_j^e = \pi_j$. Competition among banks fixes the interest rate $i > r$ on standard business loans and yields a convenient form of expected profit,

$$p(1+i) = R \quad \Rightarrow \quad \pi_j = p(vx_j - iI_j) - cI_j. \tag{3}$$

3.2 Unconstrained Investment

We first turn to the case of non-innovating firms with conservative investment strategies and little need for external funds. By Assumption 1 below, these firms are unconstrained, invest at first-best levels, take only standard bank loans and have no demand for monitoring capital. Noting the timing of decisions, we solve backwards. Anticipating the outcomes in stage (iv), we begin with stage (iii). After external financing is arranged, entrepreneurs and banks know their income shares. If the firm succeeds, the bank collects repayment $(1+i)D_u$ on the loan, leaving residual earnings $y_u^e \equiv I_u + vx_u - (1+i)D_u$ to the entrepreneur. Once investment is sunk and external funds are fixed, the firm may fail due to a lack of managerial effort. Effort may be either high or low, resulting in a high or low success probability $p > p_L$. When shirking, the success probability and expected income are low but the entrepreneur enjoys private benefits BI_u. The size of her profit stake determines whether the reward is large enough to motivate high effort. High effort

is chosen if the incentive compatibility condition holds,

$$py_u^e \geq p_L y_u^e + BI_u \quad \Leftrightarrow \quad y_u^e \geq I_u B/(p - p_L). \tag{4}$$

Assumption 1 *(i) At I_u determined by $vf'(I_u) = i$, we have $y_u^e > I_u B/(p - p_L)$.*
(ii) At I_c determined by $v\theta f'(I_c) = i$, we have $y_c^e < I_c b/(p - p_L)$, where $b < B$.

In the first-best, managerial effort is contractible and monitoring is not required. The first-best level of investment maximizes expected profit $\pi_u^e = \pi_u$ in (3) with $c = 0$. The firm invests until the marginal return is equal to the user cost of capital,

$$vf'(I_u) = i, \quad \pi_u = p(vx_u - iI_u). \tag{5}$$

Given part (i) of Assumption 1, the incentive constraint is slack at the first-best investment level. Banks are willing to lend the entire desired loan. The firm is unconstrained and exclusively relies on passive bank financing. Monitoring capital would be more expensive but can play no useful role since there is no need to improve access to external funds.

3.3 Constrained Investment

R&D intensive firms are highly productive ($\theta_c > 1$) and have large investment opportunities but little internal assets as a result of prior R&D spending, $A_c = A - (1 - \sigma)k < A_u$. Part (ii) of Assumption 1 means that these two characteristics make innovative firms financially dependent. To relax the constraint and further exploit investment opportunities, these firms might want to demand monitored finance in addition to standard bank credit. Active banks must cover additional monitoring costs. Since it is more expensive, monitoring capital is used only to the minimum extent that still guarantees the desired monitoring and certification. The required residual credit is raised from passive banks. We proceed in two steps and first assume that the firm obtains monitored finance in addition to standard credit. We then state Assumption 2 below which implies that mixed financing indeed yields higher value than passive credit alone.

In the effort stage, financial contracts and, thus, investment and debt levels are predetermined. Banks are promised repayments of $y_c^m \equiv (1+i^m)\, D_c^m$ and $(1+i)\, D_c$, respectively, leaving residual earnings $y_c^e \equiv I_c + vx_c - (1+i)\, D_c - y_c^m$ to the entrepreneur. Neither managerial nor monitoring effort is contractible, leading to a double moral hazard. Both efforts are discrete, either high or low. As before, high managerial effort raises the success probability to $p > p_L$ while monitoring reduces private benefits to $b < B$, giving bI_c if the entrepreneur is monitored, and BI_c if she is not. Monitoring thus makes shirking less rewarding. Profit shares determine whether rewards are large enough to motivate high effort. With active monitoring, managerial effort is high if

$$\begin{aligned} py_c^e &\geq p_L y_c^e + bI_c \quad \Leftrightarrow \quad py_c^e \geq \beta_c I_c, \quad \beta_c \equiv bp/(p-p_L)\,, \\ py_c^m &\geq p_L y_c^m + cI_c \quad \Leftrightarrow \quad py_c^m \geq \gamma I_c, \quad \gamma \equiv cp/(p-p_L)\,. \end{aligned} \tag{6}$$

The second condition reflects the following trade-off. Suppose the managerial incentive constraint is tight when the bank monitors. Expected repayment to the bank, py_c^m, then is high. If monitoring is neglected, the manager owner enjoys larger private benefits and prefers shirking which reduces the success probability to p_L. Expected repayment falls to $p_L y_c^m$, but the bank can assign employees hired for monitoring to other tasks generating income cI_c, leading to expected earnings equal to $p_L y_c^m + cI_c$. The incentive to monitor consists of the rise in expected income from disciplining the entrepreneur. With double moral hazard both constraints must be satisfied simultaneously. The role of monitoring is to limit managerial discretion so that entrepreneurs are incentivized with a smaller income stake, leaving a larger part of cash-flow for repayment to banks. Monitoring thus raises a firm's pledgeable income and improves access to external funds.

At the prior contracting stage, banks compete to lend to firms and propose financing contracts which include monitored finance on top of standard bank credit. Optimal financial contracts maximize the surplus π_c^e of firms subject to incentive and participation constraints, see Appendix A for details. Intuitively, since active capital is more expensive, it is only offered the *minimum* repayment y_c^m that induces monitoring effort in (6). Given this repayment, the contract demands funds D_c^m from monitors until the participation

constraint binds. Using $\gamma - c = cp_L/(p - p_L) > 0$ yields

$$py_c^m = \gamma I_c, \quad D_c^m = (py_c^m - cI_c)/R = (\gamma - c) I_c/R. \tag{7}$$

Reserving part of cash-flow for repayment to monitors reduces the entrepreneur's residual income. To assure managerial effort, the owner must keep a minimum stake $py_c^e \geq \beta_c I_c$ which is lower with monitoring than without. Hence, $\beta_c < \beta_u \equiv Bp/(p - p_L)$ since $b < B$. Both incentive payments limit the repayment that can be pledged to passive banks. Hence, the firm's debt capacity is restricted by $RD_c \leq p(I_c + vx_c) - \gamma I_c - \beta_c I_c$ where $\beta_c I_c$ and γI_c are those parts of profit that must go to the entrepreneur and the active bank to assure high management effort and monitoring. The active bank supplies funds D_c^m while the remaining credit $D_c = I_c - A_c - D_c^m$ must be offered by standard banks. Using this and $p(1 + i) = R$ as well as (7) in the entrepreneur's incentive constraint yields

$$\pi_c = p(vx_c - iI_c) - cI_c \geq \beta_c I_c - RA_c, \quad A_c = A - (1 - \sigma) k. \tag{8}$$

If binding, this constraint implicitly determines investment which is financed by monitoring capital D_c^m as in (7) and standard debt $D_c = I_c - A_c - D_c^m$ from passive banks.

Proposition 1 ***(Constrained investment)*** *With a binding financing constraint, investment is not driven by the user cost of capital but depends, instead, on pledgeable future income and on accumulated own assets.*

Figure 1 illustrates how investment is determined. The right-hand side of equation (8) is the 'incentive-line' starting out from the intercept $-A_c R$. The left-hand side is the expected profit and corresponds to the upper hump-shaped curve. Its maximum gives the virtual, unconstrained investment, $vx_c' = i$. By Assumption 1, the entrepreneur's incentive constraint is violated with this level of externally financed investment. The intersection of these two lines determines the constrained investment level as in (8). At this point, the slopes satisfy $\beta_c > p(vx_c' - i) - c > 0$. In other words, the firm earns an excess return and would like to expand investment but is credit rationed. Financing a

higher level of investment with more external funds would not be incentive compatible.[8] We can thus state:

Proposition 2 ***(Excess return)*** *Expanding investment of constrained firms would raise expected profit by* $d\pi_c/I_c = \rho$*, where* $\rho \equiv p\left(vx_c' - i\right) - c > 0$ *is the excess return.*

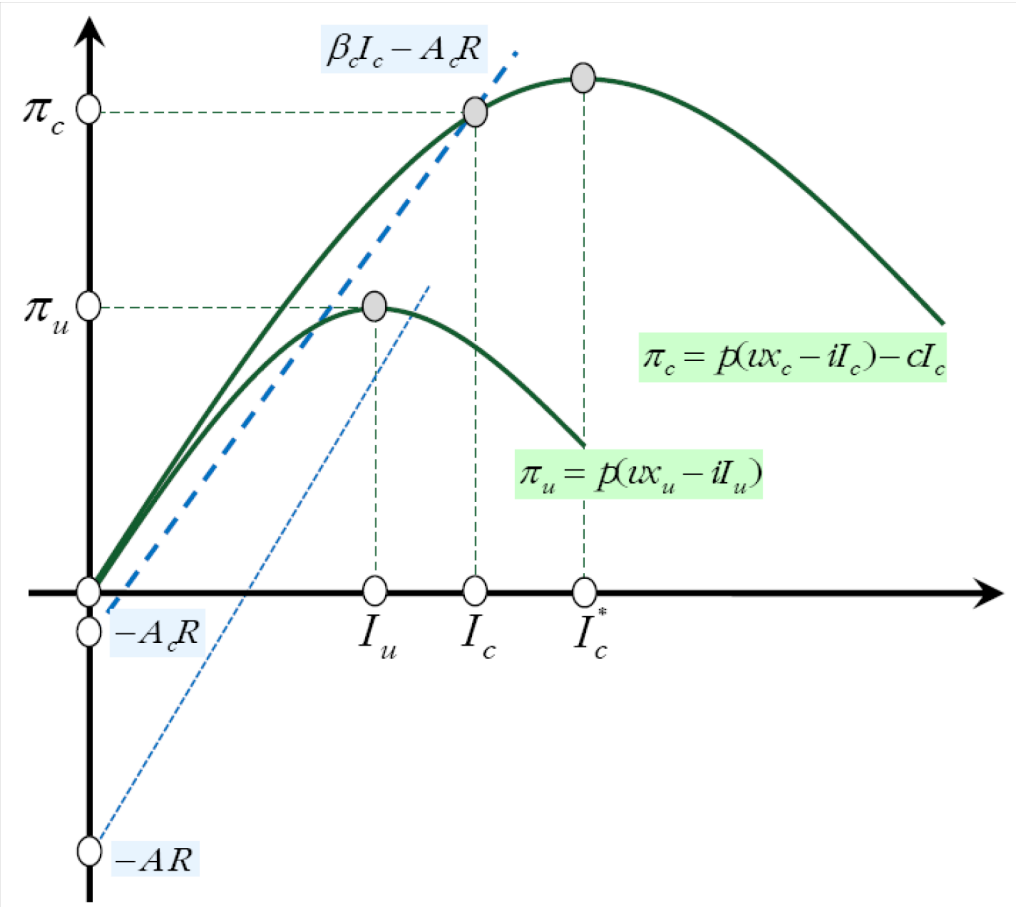

Fig. 1: Constrained and Unconstrained Firm Performance

Figure 1 compares investment and profit of constrained and unconstrained firms. Since successful R&D yields higher productivity, unconstrained investment and profit of innovative firms would clearly be larger than for non-innovative firms. When the financing

[8] A larger credit would violate incentive constraints. Even with low effort, passive banks could provide credit by discretely raising the loan rate to $i_L > i$ until $(1 + i_L) p_L = R$. If $p_L \to 0$, an unconstrained equilibrium with shirking definitely reduces value relative to a constrained equilibrium with high effort.

constraint becomes binding, investment and profits are reduced. As illustrated in Figure 1, we impose parameter restrictions such that the financing constraint represses investment and profit, but not to an extent that innovative firms would become smaller and less profitable than non-innovative firms, $I_c > I_u$ and $\pi_c > \pi_u$.[9]

Turning to the second step, we now show that mixed financing yields a higher surplus and is preferred to exclusive financing with a standard bank credit. One may illustrate this matter with Figure 1. If there was no monitoring ($\beta_c = \beta_u$), the incentive lines would be parallel. Monitoring constrains private benefits, leading to $\beta_c < \beta_u$. The incentive line of the constrained firm rotates clockwise. In relaxing the financing constraint, investment of the innovative firm expands and, since it earns an excess return, expected profit rises. The gains from monitoring are (partly) offset by the fact that monitoring costs shift down the expected profit line. The firm will thus demand monitoring capital only if the gains in relaxing the financing constraint are larger than the cost of monitoring.

More formally, we start in the absence of monitoring where $b = B$ and $c = 0$ and consider an introduction and marginal further increase of monitoring intensity m, creating costs $dc = dm$ and reducing private benefits by $db/dm < 0$. More intensive monitoring reflects an increase in monitoring productivity and creates demand for monitoring capital if the firm's expected surplus rises. To see this, take the differential of (3), $d\pi_c = \rho dI_c - I_c dc$. Monitoring adds extra costs $I_c dc$, i.e., 'informed' capital is more expensive, which directly reduces expected surplus. The benefit of attracting monitoring capital is that it facilitates investment dI_c because it boosts the firm's pledgeable income by reducing private benefits. Clearly, if the firm is severely constrained and excess return is large, the

[9] We want to emphasize a difference to Manova (2008b) who assumes an exogenous productivity distribution and identical fixed costs of firms. In our analysis, all firms have identical assets ex ante. However, firms may choose to spend on R&D, leaving them with less own assets for subsequent investment. Innovation raises investment opportunities. Compared to non-innovative firms, R&D intensive companies are endogenously smaller ex ante in terms of residual funds $A - k$, but larger ex post in terms of output. Restricting to two endogenously created levels of assets also allows a simplification relative to Holmstrom and Tirole (1997) who considered an exogenous, continuous distribution of assets.

additional investment substantially augments profits by ρdI_c which may be worth more than the extra cost $I_c dc$. Demand for monitoring capital exists if the following assumption on 'monitoring productivity' is imposed:

Assumption 2 *Monitoring ($dm = dc$) is productive and boosts firm profits if*

$$\rho\lambda > \beta_c > \rho \equiv p\left(vx_c' - i\right) - c > 0, \quad \lambda \equiv -\frac{p}{p - p_L}\frac{db}{dm} > 0. \tag{A2}$$

The assumption means that introducing a small amount of monitoring activity by engaging active investors boosts the firm's value. To show this, we define the relative increase in marginal monitoring cost by $\hat{c} \equiv dc/\beta_c$, and of monitoring intensity by $\hat{m} \equiv dm/\beta_c$.[10] For a given investment level I_c, a higher monitoring intensity yields a percentage reduction in agency costs of $\hat{\beta}_c = \hat{b} = -\lambda\hat{m}$, which implies an equally large percentage reduction $\hat{y}_c^e = -\lambda\hat{m}$ of the minimum entrepreneurial compensation. Monitoring thereby raises pledgeable income and boosts investment. Using $\hat{\sigma} \equiv d\sigma/(1-\sigma)$, the differential of the investment condition (8) gives

$$\hat{I}_c = \frac{pvx_c}{\delta I_c} \cdot \hat{v} + \frac{\beta_c}{\delta} \cdot (\lambda\hat{m} - \hat{c}) + \frac{AR}{\delta I_c} \cdot \hat{A} + \frac{(1-\sigma)\,kR}{\delta I_c} \cdot \hat{\sigma}, \quad \delta \equiv \beta_c - \rho < R, \tag{9}$$

where $R > \delta$ assures positive leverage, i.e., $dI_c/dA_c = R/\delta > 1$. Given benefits and costs, monitoring is desirable only if the net impact on expected profit is positive, i.e., $d\pi_c = \rho dI_c - I_c dc > 0$. Using $\hat{c} = \hat{m}$ and δ,

$$d\pi_c = (\rho\lambda - \beta_c)\frac{\beta_c}{\delta} I_c \cdot \hat{c} > 0. \tag{10}$$

The condition that monitoring is attractive and demand for 'informed capital' arises, is stated by the first inequality in (A2) and consists of two parts: (i) there must be a sufficiently large excess return ρ on investment so that the extra investment created by monitoring leads to a relatively large increase in expected profit. Since unconstrained firms

[10] In general, the subsequent comparative static analysis defines changes of a variable x relative to its equilibrium value prior to a given shock by $\hat{b} = db/b$. Exceptions are specially noted.

do not earn any excess return, they do not benefit from and do not demand monitoring capital. (ii) Monitoring must be productive, i.e., the elasticity λ must be sufficiently large.

We interpret financial development to mean that active banks get more productive in monitoring, i.e., monitoring intensity m increases relative to an *unchanged* marginal cost c. Since more intensive monitoring reduces private benefits of entrepreneurs, the incentive line in Figure 1 becomes flatter and rotates clockwise around the intercept. In reducing the entrepreneur's incentive compatible income, monitoring boosts the firm's debt capacity and leads to a larger level of investment.

Innovative firms have little own assets and large investment opportunities and heavily rely on external funds. Being constrained, they benefit from monitoring which improves access to capital and allows them to invest more. Innovative firms thus finance themselves from multiple sources. The more productive monitoring is, the more external funds firms can raise, and the closer they come to the unconstrained regime. We consider only a marginal increase in monitoring productivity so that credit constraints are only partly relaxed and innovative firms are still rationed.[11]

3.4 R&D Choice

Firms are assumed to be heterogeneous in their innovation potential, given by the success probability of R&D. After making a draw q' from the distribution $G(q)$, the firm chooses the R&D intensity, either k or zero. The private cost is possibly subsidized. Firms of type q' invest in R&D if $q'\pi_c - (1-\sigma)\,kR \geq q'\pi_u$, giving the cut-off[12]

$$q = (1-\sigma)\,kR/\left(\pi_c - \pi_u\right). \tag{11}$$

[11] Starting from a situation where assumption A2 holds, we must assume that the condition also holds after a marginal change in monitoring productivity. Note that A2 cannot hold in the unconstrained case with $\rho = 0$. Hence, demand for monitoring capital must vanish before financial constraints are fully relaxed. Informed capital is useful only for sufficiently constrained firms, pointing to a deep parameter restriction determining the existence of a market for informed capital.

[12] We focus on interior equilibria, $q < 1$, where the profit differential is large relative to the R&D cost.

Figure 2 shows how discrete R&D choice splits the entrepreneurial sector into innovative and non-innovative firms. Types $q' < q$ refrain from R&D spending while types $q' > q$ invest in R&D which turns them into highly productive growth companies if successful.

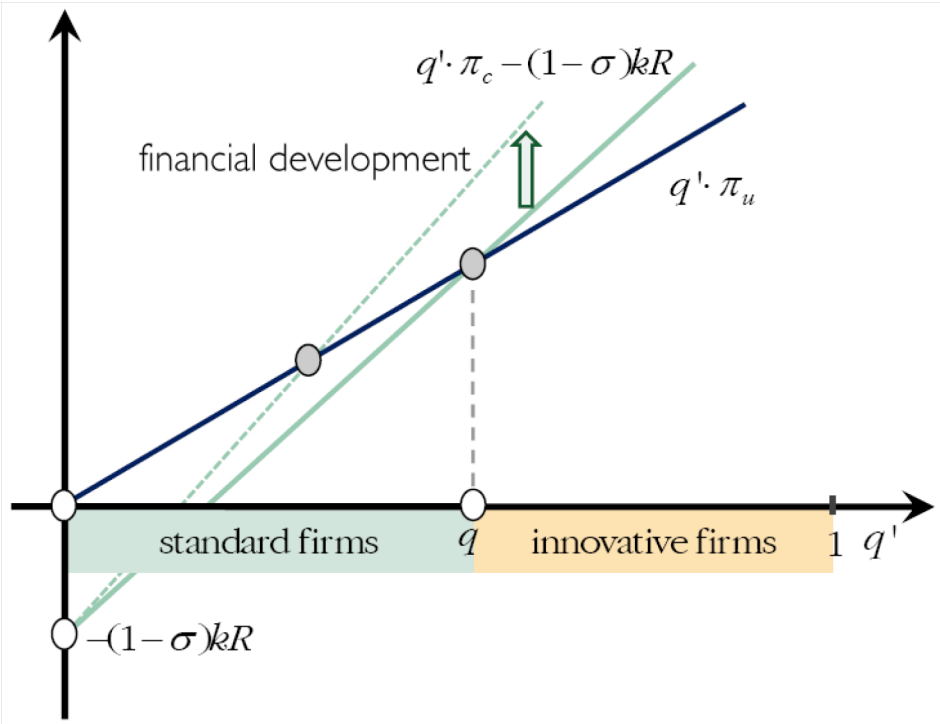

Fig. 2: R&D Choice

Ex ante, before the type of project is revealed, firms innovate with probability s_k and survive the early stage with probabilities s_c and s_u:

$$s_c = \int_q^1 q' dG(q'), \quad s_u = \int_0^q q' dG(q'), \quad s_k = \int_q^1 dG(q'). \tag{12}$$

From E firms in the entrepreneurial sector, a share s_k engages in R&D. Only $s_c < s_k$ of them continues, the remaining part $s_k - s_c$ fails in the R&D stage. Similarly, a share $1 - s_k$ does not invest in R&D and of those only a share $s_u < 1 - s_k$ continues with expansion investment. Of all $s_j E$ firms surviving the early stage, only $ps_j E$ produce output. Hence, more and more firms get eliminated over their life-cycle.

Expected profit ex ante, anticipating R&D and expansion investments, amounts to

$$\pi_E = s_u \pi_u + s_c \pi_c - (1-\sigma) kRs_k > 0. \tag{13}$$

Expected profit $\pi_E = \int_0^1 \pi_u q' dG(q') + \int_q^1 [(\pi_c - \pi_u) q' - (1-\sigma) kR] dG(q')$ is positive since $\pi_c > \pi_u > 0$, and reflects a rent on entrepreneurial ability. The square bracket is zero for the cut-off q but strictly positive for $q' > q$.

The R&D choice dichotomizes innovative sector firms into cash-poor growth companies and cash-rich, but less productive non-innovative firms. Innovative growth companies are highly productive but prior R&D leaves them with low assets. Credit rationing prevents them to fully exploit investment opportunities. Hence, early stage R&D endogenizes the fraction of financially dependent firms in the innovative sector. Financing constraints operate on the extensive and intensive margins of investment.

3.5 General Equilibrium

Income is spent on goods according to preferences that are assumed separable in consumption and private benefits B_i (leisure). Utility is linearly homogeneous in consumption c_{iN} and c_{iE} of numéraire and innovative sector goods. Given end of period income y_i and a relative price v, demand follows from

$$u_i = \max_{c_{iN}, c_{iE}} u(c_{iN}, c_{iE}) + B_i \quad s.t. \quad c_{iN} + v c_{iE} \leqslant y_i. \tag{14}$$

Given incentive compatibility, private benefits are zero. Welfare thus equals real income, $u_i = y_i / v_D$, and changes by $\hat{u}_i = \hat{y}_i - \hat{v}_D$ where a hat denotes relative changes. The price index $v_D(v)$ adjusts by $\hat{v}_D = \eta \hat{v}$. Without loss of generality, we specialize to Cobb Douglas preferences so that expenditure shares $\eta \equiv v c_{iE} / y_i$ and $1 - \eta \equiv c_{iN} / y_i$ are fixed.

Equilibrium reflects optimal behavior, budget constraints, and market clearing in loanable funds and sectoral output markets. By Walras' law, one of these conditions is implied by the others. The loanable funds market is

$$A(1-E) + A_c(s_k - s_c) E + A_u(1 - s_k - s_u) E = \textstyle\sum_j (I_j - A_j) s_j E + Z + \sigma k s_k E.$$

The supply of loanable funds on the left-hand side consists of (i) savings of $1-E$ investors; (ii) residual savings $A_c = A - (1-\sigma) k$ of failed innovative firms; and (iii) residual savings

$A_u = A$ of failed non-innovative firms. Demand on the right-hand side includes (i) loans for expansion investments of both types of firms; (ii) investment in the safe Z-technology; and (iii) government debt issued to finance upfront R&D subsidies. Rearranging yields

$$A = Z + K \cdot E, \quad K \equiv s_k k + I_E, \quad I_E \equiv \textstyle\sum_j s_j I_j, \tag{15}$$

where K denotes average investment per firm, consisting of R&D and expansion investment, and Z is residual investment in the Ricardian sector.[13]

At the end of the period, the government collects a per-capita tax t_L from workers. Since R&D subsidies are due at the beginning, it must raise funds $\sigma k s_k E$ on the deposit market to subsidize innovating firms, and it pays back R times as much at the end of period. In addition, the country may impose an ad-valorem tariff τ on imports of innovative goods. Buyer arbitrage links domestic and foreign prices by $v = (1+\tau)\, v^*$. Given aggregate supply and demand of innovative goods, X_E and C_E, and noting tariff revenue T, the fiscal budget constraint is

$$t_L L + T = \sigma k \cdot s_k E R, \quad T \equiv \tau v^* \left(C_E - X_E\right). \tag{16}$$

A person i may have different income. Workers are subject to a lump-sum tax t_L, giving income $y_L = 1 - t_L$ per capita. Investors earn $y_I = AR$. Managerial talent being scarce, entrepreneurs obtain rents on average, $y_E = AR + \pi_E$. Total income is $Y = \pi_E E + AR + y_L L$. Define average values by $x_E \equiv \sum_j s_j x_j$, and similarly for I_E. Substituting π_E and π_j, together with the fiscal constraint yields aggregate income $Y = \left[p\left(I_E + v x_E\right) - R I_E - c I_c s_c - k R s_k\right] E + T + AR + L$, where cI_c is the resource cost of monitoring per innovative firm which reduces sector 2 output. Use now the capital market condition (15), define sectoral outputs X_E and X_N and note the consumer budget in (14) to obtain the income expenditure identity. The trade balance $\left(C_N - X_N\right) + v^* \left(C_E - X_E\right) = 0$ follows upon using $v = (1+\tau)\, v^*$ and T,

$$C_N + v C_E = Y = v X_E + X_N + T, \quad X_E \equiv x_E p E, \quad X_N \equiv L + Z R + I_E p E - c s_c I_c E. \tag{17}$$

[13] Deep fundamentals determine the value of K. We assume throughout that parameters A and E are such that $Z > 0$, assuring diversification in production.

Arbitrage and linearity of the Ricardian investment technology fixes the deposit factor R and the loan rate i by (3). Innovative sector investment I_E is determined by interest rates, the relative price v, and the composition of firms which results from a discrete innovation decision. Equilibrium in the loanable funds market residually determines investment Z in the numéraire sector. Computing aggregate income Y yields the demand side and the trade balance. World market clearing for the innovative good fixes the relative price v. Finally, Walras' law implies equilibrium in the world market for numéraire goods. In a closed economy, v clears the innovative goods market $C_E = X_E$, implying market clearing in the numéraire sector as well.

4 Small Open Economy

We study how three distinct areas of policy intervention, import protection, R&D subsidies and financial development, can shape the trade structure and affect welfare in a small open economy. Buyer arbitrage links domestic and foreign prices by $v = (1+\tau)\, v^*$ where τ is an import tariff. When analyzing tariffs, we assume the country to be an importer of innovative goods.[14] A small open economy cannot affect the common world price v^* of the innovative good in all other countries. Hence, import protection raises the domestic price by $\hat{v} = \hat{\tau} \equiv d\tau/(1+\tau)$. To avoid complicated tax base effects, we assume the initial equilibrium to be untaxed, i.e., $\sigma = t_L = \tau = 0$ at the outset.

4.1 Firm Level Adjustment

Innovative and conservative firms react in different ways to economic shocks. Given that interest rates are pinned down in the Ricardian sector, investment of unconstrained firms in (5) exclusively depends on the output price,

$$\hat{I}_u = \varepsilon \cdot \hat{v}, \quad d\pi_u = pvx_u \cdot \hat{v}, \quad \varepsilon \equiv \frac{-x'(I_j)}{I_j x''(I_j)}. \tag{18}$$

[14] If the country were an exporter, we could investigate an export tax to raise the domestic price.

A higher price boosts investment and profits of conservative firms, where the change in profits reflects the envelope theorem.

By way of contrast, constrained investment is determined by a firm's debt capacity, see (8). Investment is not driven by the user cost of capital but rather depends on the determinants of pledgeable income, such as monitoring intensity and own assets A_c. For example, improvements in the banking sector may result in better oversight of firms which reduces incentive compatible entrepreneurial compensation and strengthens pledgeable income. We interpret financial development as an increase in monitoring productivity of active banks, given a fixed marginal cost c. The investment response is stated in (9). To compare with unconstrained firms, we rewrite this condition as

$$\hat{I}_c = (\varepsilon + \phi_v) \cdot \hat{v} + \phi_\sigma \cdot \hat{\sigma} + \phi_m \cdot \hat{m}, \tag{19}$$

where coefficients are defined as

$$\phi_v \equiv \frac{vpx_c}{\delta I_c} - \varepsilon, \quad \phi_\sigma \equiv \frac{kR}{\delta I_c}, \quad \phi_m \equiv \frac{\lambda \beta_c}{\delta}.$$

Setting ϕ-coefficients to zero recovers the unconstrained case where investment is independent of R&D subsidies and monitoring, leaving $\hat{I}_c = \varepsilon \hat{v}$ as with noninnovating firms.

A higher price stimulates investment of constrained firms although the price elasticity is generally not the same as with unconstrained firms. The mechanism, however, is entirely different. The stimulus comes from increased earnings, not from the change in the user cost. Financial sector development in terms of higher monitoring productivity also raises the firm's pledgeable income and thereby boosts investment by facilitating access to external credit. Since monitoring cannot play a useful role with more conservative, unconstrained firms, it does not affect their investment. Finally, the R&D subsidy strengthens the firm's own funds after R&D spending, thereby relaxes the financing constraint and boosts expansion investment. This is a novel role for R&D subsidies! The direct effect of the subsidy is to reduce private R&D cost and stimulate innovation on the extensive margin. However, the subsidy also helps innovative firms to better exploit the productivity gains from innovation and the associated investment opportunities which earn an above

normal, excess return. Since the R&D subsidy is already sunk at the expansion stage, this second effect does not exist when firms are unconstrained.

Constrained firms earn an excess return on investment. For this reason, profits rise with higher investment levels, $d\pi_c = pvx_c \cdot \hat{v} + \rho I_c \cdot \hat{I}_c$. Relaxing the financing constraint and boosting investment yields additional profit in proportion to the excess return ρ.[15] Substituting the investment response gives

$$d\pi_c = [pvx_c + \rho I_c (\varepsilon + \phi_v)] \cdot \hat{v} + \rho I_c \phi_\sigma \cdot \hat{\sigma} + \rho I_c \phi_m \cdot \hat{m}. \tag{20}$$

The R&D subsidy boosts profit ex ante, net of the subsidy as in (11), but does not directly change profits π_j in the expansion stage. Nevertheless, the subsidy indirectly boosts profit since it relaxes the financing constraint and allows the firm to invest more at an above-average, excess return.

Any policy that strengthens expected profits of innovative firms relative to others leads more firms at an early stage to pursue an innovation strategy. Directly subsidizing the R&D cost similarly boosts innovation. Noting $\hat{\sigma} \equiv d\sigma$, the impact on the innovation threshold is $\hat{q} = -(d\pi_c - d\pi_u)/(\pi_c - \pi_u) - \hat{\sigma}$ which yields $\hat{q} = -pv\frac{x_c - x_u}{\pi_c - \pi_u}\hat{v} - \frac{\rho I_c}{\pi_c - \pi_u}\hat{I}_c - \hat{\sigma}$. The second term would not be present in the first-best case. The subsidy directly encourages innovation by reducing net R&D cost. When firms are constrained, the subsidy additionally boosts investment and strengthens profits and thereby induces even more innovation. The direct effect would shifts up the profit line in Figure 2 (not drawn), while the indirect effect rotates it counterclockwise. The figure also illustrates the effect of financial development on innovation. Since monitoring boosts the debt capacity of constrained firms, it facilitates larger investments with an above-normal return and thereby selectively strengthens profits of innovative relative to non-innovative firms. As shown in Figure 2, the profit line net of R&D cost rotates to the left and thereby lowers the innovation threshold. Formally, by substituting the investment response in (19), we find

[15] Setting $\rho = 0$ recovers the unconstrained case. Firms would not want monitoring capital on top of passive bank credit so that $c = 0$. The impact on profit would be as in (18).

a change in the cut-off probability equal to

$$\hat{q} = -\mu_v \cdot \hat{v} - \mu_\sigma \cdot \hat{\sigma} - \mu_m \cdot \hat{m}, \tag{21}$$

where all coefficients are defined in positive values,

$$\mu_v \equiv \frac{pv\left(x_c - x_u\right) + \rho\left(\varepsilon + \phi_v\right) I_c}{\pi_c - \pi_u}, \quad \mu_\sigma \equiv 1 + \frac{\rho\phi_\sigma I_c}{\pi_c - \pi_u}, \quad \mu_m \equiv \frac{\rho\phi_m I_c}{\pi_c - \pi_u}.$$

A declining threshold means that more firms innovate. All three shocks boost innovation at the extensive margin, but only import protection and the R&D subsidy would do so in a first-best world. Monitoring capital would not be demanded and would not exist if none of the firms were constrained. When more firms adopt an innovation strategy, the share of highly productive firms rises, and so does average productivity in the industry. To evaluate welfare consequences, we also need to know the change in expected profit ex ante, taking account of R&D costs as well. Since compositional effects are related by $qds_k = ds_c = -ds_u$, average profit in (13) rises by $d\pi_E = s_u d\pi_u + s_c d\pi_c + kRs_k d\sigma + \left[\left(\pi_c - \pi_u\right) q - kR\right] ds_k$. The square bracket is zero by R&D choice in (11). Noting $x_E = \sum_j s_j x_j$, expected profit changes by

$$d\pi_E = \left[pvx_E + \rho s_c I_c\left(\varepsilon + \phi_v\right)\right] \cdot \hat{v} + \left[s_k kR + \rho s_c I_c \phi_\sigma\right] \cdot \hat{\sigma} + \rho s_c I_c \phi_m \cdot \hat{m}. \tag{22}$$

4.2 Supply, Demand and Welfare

The next step is to show how firm-level investment and innovation determines sectoral supply, national income and demand. Aggregate supply $X_E = x_E pE$ changes in proportion to $x_E = s_c x_c + s_u x_u$ which is a measure of average output of innovative and non-innovative firms. Out of E firms initially, only a share $s_c + s_u = \int_0^1 q' dG\left(q'\right)$ survives the early stage and p of those arrive in the mature production stage. Noting the compositional effects $ds_c = -ds_u = -qg\left(q\right) dq$ as a result of innovation choice, average output changes by $dx_E = s_c dx_c + s_u dx_u - \left(x_c - x_u\right) qg\left(q\right) dq$, or

$$\hat{X}_E = \zeta_{x,v} \cdot \hat{v} + \zeta_{x,\sigma} \cdot \hat{\sigma} + \zeta_{x,m} \cdot \hat{m}, \tag{23}$$

where output elasticities are all positive and $\alpha = I_j x_j'/x_j$,

$$\begin{aligned}
\zeta_{x,v} &\equiv \alpha\left(\varepsilon + \frac{s_c x_c}{x_E}\phi_v\right) + \frac{x_c - x_u}{x_E} q^2 g(q)\,\mu_v, \\
\zeta_{x,\sigma} &\equiv \alpha\frac{s_c x_c}{x_E}\phi_\sigma + \frac{x_c - x_u}{x_E} q^2 g(q)\,\mu_\sigma, \\
\zeta_{x,m} &\equiv \alpha\frac{s_c x_c}{x_E}\phi_m + \frac{x_c - x_u}{x_E} q^2 g(q)\,\mu_m.
\end{aligned}$$

Aggregate supply reflects intensive and extensive margins. A higher price for innovative goods, for example, boosts investment and output of both types of firms. This *intensive margin* is related to the first part of the ζ-elasticities. Further, a higher price induces more firms to innovate. For each firm that is turned from a non-innovative producer into a highly productive growth company, supply rises on the *extensive margin* by the difference in output levels $x_c - x_u$, times the mass of firms moving to a higher productivity level. An R&D subsidy raises investment of constrained firms by ϕ_σ and translates into higher output $\alpha\phi_\sigma$ per firm. Since the subsidy stimulates investment only of constrained innovative firms, the average output gain is scaled by the share $s_c x_c/x_E$. In a first-best, the subsidy does not affect firm scale ($\phi_\sigma = 0$) but it still boosts innovation ($\mu_\sigma = 1$) and aggregate output on the extensive margin. Financial sector development can play no role at all in a first-best world (both $\phi_m = \mu_m = 0$).

National income consists of capital income of investors and entrepreneurs plus wages of workers, $Y = AR + \pi_E E + (1 - t_L) L$. Using the fiscal budget and starting from an untaxed position with $v = v^*$, it changes by $dY = Ed\pi_E - ks_k ERd\sigma + v(C_E - X_E)\,d\tau$. Substituting the change in expected profits of a new firm in (22) yields

$$\hat{Y} = \left(\eta_s + \zeta_{y,v}\right)\cdot\hat{v} + \zeta_{y,\sigma}\cdot\hat{\sigma} + \zeta_{y,m}\cdot\hat{m} + (\eta - \eta_s)\cdot\hat{\tau}, \tag{24}$$

where $\eta \equiv vC_E/Y$ and $\eta_s \equiv vX_E/Y$ are the GDP shares of innovative sector demand and supply (compare also 14), and $\eta_i \equiv s_c I_c/(vpx_E)$ is the share of constrained investment in the expected value of output per firm. Using (19) and (A2), income elasticities are

$$\zeta_{y,v} \equiv \rho\eta_i\eta_s(\varepsilon + \phi_v), \quad \zeta_{y,\sigma} \equiv \rho\eta_i\eta_s\phi_\sigma, \quad \zeta_{y,m} \equiv \rho\eta_i\eta_s\phi_m,$$

Note how the excess return ρ magnifies income gains. In the first-best case, $\rho = 0$ and $\hat{Y} = \eta_s \cdot \hat{v} + (\eta - \eta_s) \cdot \hat{\tau}$. The impact of R&D subsidies and financial development arises only via the effect on financing constraints. These policies thus help to implement additional investments with an above normal rate of return while the alternative use of resources in the numéraire sector, i.e., $Z = A - KE$ in (15), would only earn a normal return, giving ZR at the end of period. The income gains are, thus, proportional to the excess return ρ earned by constrained firms in the innovative sector.

Assuming constant expenditure shares in (14), the demand allocation is $vC_E = \eta Y$. Using the change in national income in (24), this yields

$$\hat{C}_E = \hat{Y} - \hat{v} = -\left(1 - \eta_s - \zeta_{y,v}\right) \cdot \hat{v} + \zeta_{y,\sigma} \cdot \hat{\sigma} + \zeta_{y,m} \cdot \hat{m} + (\eta - \eta_s) \cdot \hat{\tau}. \tag{25}$$

Without a financing constraint ($\rho = 0$), a higher price shrinks demand by $\hat{C}_E = -(1 - \eta_s)\hat{v}$. The demand reduction is weakened by the income gains that arise when constrained firms are able to expand investment. These gains are proportional to the excess return earned by R&D intensive firms. In the first-best situation, a small R&D subsidy would not affect consumption, i.e., the gains to firms are completely offset by taxes, and financial development would be useless with unconstrained firms.

A country's trade structure depends on how deep fundamentals affect excess demand, $\xi \equiv C_E - X_E$. Defining $\hat{\xi} \equiv v d\xi / Y$ yields $\hat{\xi} = \eta \hat{C}_E - \eta_s \hat{X}_E$, or

$$\hat{\xi} = -\xi_v \cdot \hat{v} - \xi_\sigma \cdot \hat{\sigma} - \xi_m \cdot \hat{m} + (\eta - \eta_s)\, \eta \cdot \hat{\tau}, \tag{26}$$

where coefficients are, using demand and supply elasticities in (23-24),

$$\begin{aligned}
\xi_v &\equiv \left(1 - \eta_s - \zeta_{y,v}\right) \eta + \zeta_{x,v} \eta_s > 0, \\
\xi_\sigma &\equiv \zeta_{x,\sigma} \eta_s - \zeta_{y,\sigma} \eta = \left[\alpha \frac{s_c x_c}{x_E} - \rho \eta \eta_i\right] \phi_\sigma \eta_s + \frac{x_c - x_u}{x_E} q^2 g(q)\, \mu_\sigma \eta_s > 0, \\
\xi_m &\equiv \zeta_{x,m} \eta_s - \zeta_{y,m} \eta = \left[\alpha \frac{s_c x_c}{x_E} - \rho \eta \eta_i\right] \phi_m \eta_s + \frac{x_c - x_u}{x_E} q^2 g(q)\, \mu_m \eta_s > 0.
\end{aligned}$$

As long as ρ is not too large, $1 - \eta_s > \zeta_{y,v}$ must hold which implies $\xi_v > 0$.[16] As long as

[16] In the first-best case, $\rho = \phi_j = \mu_m = 0$ and $\mu_\sigma = 1$, leaving $\xi_m = 0$, $\xi_\sigma = \frac{x_c - x_u}{x_E} q^2 g(q)\, \eta_s$ and $\xi_v \equiv (1 - \eta_s)\, \eta + \left[\alpha \varepsilon + \frac{x_c - x_u}{x_E} q^2 g(q)\, \mu_v\right] \eta_s > 0$ with $\mu_v \equiv \frac{pv(x_c - x_u)}{\pi_c - \pi_u}$.

the square bracket is positive, the other coefficients are positive as well. To see this, use $\alpha = I_c x_c'/x_c$, $\eta_i = s_c I_c/(vpx_E)$ and $\rho = p(vx_c' - i) - c$ to obtain

$$\alpha \frac{s_c x_c}{x_E} - \rho\eta\eta_i = [vpx_c' - \rho\eta]\,\eta_i = [(1-\eta)\,vpx_c' + \eta \cdot (ip + c)]\,\eta_i > 0.$$

A higher relative price reduces excess demand and, thereby, imports of innovative goods. A small (tax-financed) R&D subsidy has the same effect although it appears ambiguous a priori since the subsidy also boosts income and demand which raises the trade deficit. However, the supply effect clearly dominates. The same holds for monitoring intensity which expands investment and supply and thereby reduces excess demand.

In equilibrium, entrepreneurs do not consume private benefits and active banks do not divert monitoring activities. Financial incentives prevent shirking. Welfare is equal to real income, $U = Y/v_D$, where v_D is the price index. Welfare changes by $\hat{U} = \hat{Y} - \eta\hat{v}$, or

$$\hat{U} = [\rho\eta_i\eta_s(\varepsilon + \phi_v) - (\eta - \eta_s)] \cdot \hat{v} + \rho\eta_i\eta_s\phi_\sigma \cdot \hat{\sigma} + \rho\eta_i\eta_s\phi_m \cdot \hat{m} + (\eta - \eta_s) \cdot \hat{\tau}. \qquad (27)$$

In the first-best, $\hat{U} = -(\eta - \eta_s) \cdot (\hat{v} - \hat{\tau})$. A higher price reduces welfare of an import country with $\eta > \eta_s$ due to a negative terms of trade effect.[17] However, a higher price strengthens pledgeable income, relaxes financing constraints and allows R&D intensive firms to realize unexploited investment opportunities with positive net value. This magnifies national income in proportion to the excess return where the gain is weighed by the investment share of constrained firms in total output times the GDP share of the innovative sector, and also depends on the strength of the investment response. When the output price is given, a small R&D subsidy boosts welfare since it relaxes the financing constraint. It thereby strengthens income by stimulating constrained investment of innovative firms. Financial sector maturation, as measured by a higher monitoring productivity m, improves firms' access to external finance and boosts investment and profits. Financial development similarly raises welfare in proportion to ρ.

[17] Introducing a tariff in a small open economy would raise the domestic price by the same amount, $\hat{v} = \hat{\tau}$, leaving a zero welfare effect.

4.3 Policy Intervention

The following propositions summarize the consequences of seemingly different areas of policy intervention in a small open economy. We first turn to classical trade policy, consisting here of protection by raising tariffs. Import tariffs on innovative goods raise the domestic price and generate tax revenue which is channeled back to the private sector to increase disposable income of workers, see (16).

Proposition 3 ***(Protection)*** *In a small open economy, a higher price boosts investment and output of all firms in the innovative sector, but disproportionately raises profits of constrained firms. It thereby induces more innovation, strongly expands aggregate supply and reduces the trade deficit of the innovative sector. National welfare rises in proportion to the excess return on investment of constrained firms.*

The statements can be verified by the comparative static results in the preceding two subsections. In a small open economy facing a fixed world price v^*, import tariffs raise the domestic price one to one, $\hat{v} = \hat{\tau}$. Unconstrained firms invest more in response to a higher marginal return on capital. Innovative firms are able to invest more since a higher price strengthens pledgeable earnings and therefore relaxes the financing constraint, see (19). Since innovative firms earn an excess return on capital, a higher price boosts profits relatively more than profits of non-innovating firms which strengthens incentives to invest in R&D and leads more firms to innovate, see (18), (20) and (21). Aggregate supply expands on the intensive and extensive margins, reflecting a larger scale of all firms plus the fact that a larger share invests in R&D and switches from a low to a high output regime. Although aggregate income and demand rise as well, protection reduces the trade deficit in the innovative sector.[18] Since a higher domestic price boosts pledgeable income of innovative firms, it facilitates investments with an above normal, excess return on

[18] Evaluating (26) yields $\hat{\xi} = -\left[\left(1-\eta-\zeta_{y,v}\right)\eta + \zeta_{x,v}\eta_s\right] \cdot \hat{\tau}$ which is negative as long as the excess return ρ and, thus, $\zeta_{y,v} = \rho\eta_i\eta_s\left(\varepsilon+\phi_v\right)$ are small.

capital, yielding a welfare gains of $\hat{U} = \rho\eta_i\eta_s(\varepsilon + \phi_v)\hat{\tau}$, see (27).[19] This result might justify a small level of protection to help 'infant industries' with many innovative and financially dependent firms that are unable to fully exploit their growth opportunities.

The existence of financing constraints might be rooted in weak institutions like bad accounting rules, little investor protection and other weaknesses in corporate governance. These shortcomings allow for managerial discretion and autonomy (high value of β_c) and, thus, narrow down pledgeable income and the financing capacity of firms. They could also be due to a rather immature financial sector which performs little effective monitoring and oversight of firms and is unable to facilitate firms' access to external funding. While at least a small degree of protection might help to relax financing constraints and yield welfare gains, other policies may target more directly the root of the problem. While tariff protection indiscriminately benefits all firms, an R&D subsidy selectively favors R&D intensive firms which tend to be financially constrained, earn an above normal return on capital and should thus exploit investment opportunities to a larger extent.

Proposition 4 ***(R&D subsidy)*** *In a small open economy with a fixed output price, an R&D subsidy relaxes the financing constraint and stimulates investment, output and (expansion stage) profits of innovative firms while non-innovating firms are not affected. The subsidy boosts innovation and thereby raises the share of growth companies in the innovative sector. Aggregate supply expands on intensive and extensive margins and reduces the trade deficit or raises the trade surplus in R&D intensive goods. National welfare rises in proportion to the excess return on investment of constrained firms.*

Note that the subsidy raises investments I_c and profits π_c in the expansion stage only if firms are constrained. The subsidy always raises the net value $q'\pi_c - (1-\sigma)kR$ of an R&D intensive firm and therefore boosts the value of an innovation strategy relative to

[19] The welfare gains of protection would also be present in the absence of monitoring capital as long as some firms are financially constrained. Monitoring relaxes financial constraints, thereby reduces the excess return ρ of constrained firms and dampens the gains from protection. A smaller share η_i of constrained firms similarly reduces the potential for welfare gains.

the value of $q'\pi_u$ available without R&D spending. Hence, a larger share of firms chooses innovation, i.e., $\hat{q} = -\mu_\sigma \hat{\sigma} < 0$ in (21), where $\mu_\sigma = 1$ in the absence of financial frictions. When access to credit is limited, the subsidy not only reduces the cost of early stage R&D but also helps financially dependent firms to earn an excess return $\rho > 0$ on larger 'follow on' investments. As early stage R&D investments become more profitable (π_c rises relative to π_u), the effect of the R&D subsidy on aggregate innovation gets reinforced, $\mu_\sigma > 1$. Aggregate welfare rises by $\hat{U} = \rho\eta_i\eta_s\phi_\sigma\hat{\sigma}$ in this case.[20]

Finally, we turn to financial sector development, meaning that active banks learn to monitor firms more effectively without any increase in the marginal cost of monitoring. The emergence of specialized intermediaries such as investment banks, venture capitalists or 'Hausbanken' with close ties to their client firms is driven by the existence of constrained firms. The role of these intermediaries is to improve access to the capital market by monitoring firms, containing possible managerial misbehavior and, thereby, raising a firm's debt capacity. These banks perform a certification role. Observing that a firm attracts financing from an active investment bank, other banks can trust in good corporate governance and will be able to lend more as well. By this mechanism, financial sector maturation improves access to external financing and facilitates investment of constrained, innovative firms. Unconstrained firms have no problem in raising funds. They do not demand monitoring capital and do not benefit from financial development. The following statements are verified by tracing the effects of $\hat{m}$ in Sections 5.1-2, setting other shocks to zero. Note that this scenario has no counterpart in an undistorted economy since demand for monitoring capital arises only if a part of firms has severe problems to get funded (see the second part of Section 4.3).

Proposition 5 ***(Financial development)*** *More productive monitoring relaxes financing constraints and stimulates investment, output and profits of innovative firms while*

[20] An R&D subsidy yields welfare gains if a positive share of firms is financially constrained. If the share η_i of constrained investment approaches zero, the welfare gains from R&D subsidies disappear since we have excluded other externalities such as innovation spillovers.

non-innovating firms are not affected. Financial development boosts R&D and raises the share of growth companies. Aggregate supply expands on intensive and extensive margins, leading to a lower trade deficit or a higher trade surplus in R&D intensive goods. National welfare rises in proportion to the excess return on investment of constrained firms.

Suppose all countries were fully symmetric with the same fraction of firms being financially constrained ex ante. Let us improve only one country's financial development in that world. Then, this country would become a net exporter of R&D intensive goods and the other countries would become net importers thereof. This illustrates the role of financial development as a source of comparative advantage.

We have discussed three rather different policy areas that could boost welfare when part of innovative sector firms are financially constrained. Can these policies be compared in any way? Given a certain improvement in financial sector efficiency, what is the size of the R&D subsidy and of tariff protection that would yield the same welfare gains?

Proposition 6 ***(Relative policy effectiveness)*** *In a small open economy, tariff protection, R&D subsidies and financial development have equivalent effects on constrained investment and national welfare, if the shocks are related by* $vpx_c\hat{\tau} = kR\hat{\sigma} = \beta_c I_c \lambda \hat{m}$.

Using $\hat{v} = \hat{\tau}$ in a small open economy, and dividing the relationship by δI_c yields $(\varepsilon + \phi_v)\,\hat{\tau} = \phi_\sigma \hat{\sigma} = \phi_m \hat{m}$ and, thus, equally large effects of all three policies on constrained firm level investment, see (19), and on national welfare, see (27). Observe, however, that this policy equivalence does not carry over to innovation or aggregate supply. Looking at the change in the innovation threshold in (21) shows that the R&D subsidy boosts innovation more than financial sector development since it encourages innovation even in the absence of financial frictions while more intensive monitoring does not. A similar argument applies to tariff protection.

This paper argues that the structure of lending is important as some investors are more active than others in exercising oversight and control and can, thus, be instrumental

in facilitating investment by improving access to external funds. In our model, active intermediation is tightly connected to the existence of innovative and constrained firms. To derive new, empirically testable implications on the financial structure of industries, one might look at the volume of monitored financing $D_M E$ as a share of total external lending $D_E E$ where $D_M \equiv s_c D_c^m$ and $D_E \equiv s_u D_u + s_c (D_c + D_c^m)$. With details given in Appendix B, we can state the following testable prediction:

Proposition 7 ***(Financial Structure)*** *(i) Financial development and R&D subsidies raise the industry share of active financing in total lending. (ii) Protection has an ambiguous effect on the industry composition of lending.*

A given policy may affect the share D_M/D_E by a selection and a scale effect. All three shocks imply a positive *selection effect*. Since they lead more firms to adopt an R&D intensive growth strategy, they raise the aggregate lending ratio. A larger share of firms becomes constrained and demands monitoring capital on top of standard bank financing while a smaller share relies exclusively on standard credit. The lending share is also influenced by a *scale effect*. When firms invest more, they become more dependent on external financing. The certification effect means that the presence of monitors allows firms to raise disproportionately more standard credit.[21] Hence, the lending ratio D_M/D_E might fall if the scale scale effect strongly raises the denominator. Tariff protection expands investment and passive credit of both types of firms so that the scale effect becomes negative and offsets the positive selection effect (under mild conditions, see Appendix B). Tariff protection implies no clear-cut pattern of the lending ratio. By way of contrast, R&D subsidies and financial development only expand constrained firms which are intensive in monitoring capital. Appendix B shows that these policies can yield a positive scale effect on the share of active to total lending which reinforces the selection effect. A sufficient condition is that there be not too many constrained firms in the initial

[21] Using the definition of γ in (7), the level of monitored credit per innovative firm is a fixed proportion of investment, $D_c^m/I_c = cp_L/((p-p_L)R)$. The financial identity $1 = A_c/I_c + D_c^m/I_c + D_c/I_c$ thus implies that the ratio D_c/I_c rises with investment.

equilibrium (s_c small). Even if this condition is not fullfilled, the selection effect could still dominate and yield the result (i) in the Proposition.

5 Large Open Economies

In a large open economy, a supply side expansion reduces the world price of innovative goods which feeds back negatively on the domestic economy since a lower price erodes the financing capacity of constrained firms and leads to a counterveiling welfare effect. In analyzing world equilibrium, we assume the home country to be an importer of innovative goods so that the rest of the world in total must be exporting, although each individual foreign country may be an importer or an exporter.[22] When the home economy is importing, the domestic price rises with tariff protection, $v = (1+\tau)\, v^*$, relative to the common world price v^*. At the outset, $\tau = 0$ and $v = v^*$. World market equilibrium requires $d\xi + \sum_j d\xi^j = 0$ where ξ^j is excess demand in other countries. Multiply by $v = v^*$, divide by world GDP, use country j's GDP share by $\omega^j \equiv Y^j/(Y + \sum_j Y^j)$, implying $\omega + \sum_j \omega^j = 1$, and define $\hat{\xi}^j \equiv v^* d\xi^j / Y^j$. Global market clearing $\hat{\xi}^* \equiv \omega\hat{\xi} + \sum_j \omega^j \hat{\xi}^j = 0$ pins down the impact on the common price. Protection relates domestic and foreign prices by $\hat{v} = \hat{v}^* + \hat{\tau}$. Using this, domestic excess demand changes as in (26) while excess demand in foreign countries changes by $\hat{\xi}^j = -\xi_v^j \cdot \hat{v}^*$ which yields

$$\hat{v}^* = -\omega \frac{\xi_v - (\eta - \eta_s)\,\eta}{\xi_v^*} \cdot \hat{\tau} - \omega \frac{\xi_\sigma}{\xi_v^*} \cdot \hat{\sigma} - \omega \frac{\xi_m}{\xi_v^*} \cdot \hat{m}, \quad \xi_v^* \equiv \omega\xi_v + \textstyle\sum_j \omega^j \xi_v^j, \tag{28}$$

where ξ_v^* is the GDP weighted average of individual country elasticities. By the same argument as in (26), the term $\xi_v - (\eta - \eta_s)\,\eta = \left(1 - \eta - \zeta_{y,v}\right)\eta + \zeta_{x,v}\eta_s$ is positive if ρ is not too large. The small open economy case results if the number of countries n gets large. This is most easily seen in the symmetric case where $\xi_v^* = n\omega\xi_v$, leading to $\hat{v}^* = -\left(\xi_\sigma / \left(n\xi_v\right)\right)\hat{\sigma}$, for example. As $n \to \infty$ (implying $\omega \to 0$), an isolated shock to the

[22] We assume at least two foreign countries to show how domestic policy can at the same time have positive and negative effects on foreign countries' welfare, depending on whether they are net importers or net exporters of the innovative good.

domestic economy has a negligible impact on the world price. In a closed economy with $n = \omega = 1$, protection is irrelevant and the equilibrium price follows from $\hat{\xi} = 0$ in (26).

5.1 Tariff Protection

If the home economy introduces an import tariff, it raises the domestic price above the world price level, $\hat{v} = \hat{v}^* + \hat{\tau}$. The trade deficit shrinks which creates excess supply on the world market and depresses the world price, see (28). Since $\omega\xi_v/\xi_v^* < 1$, protection raises the domestic price, but less than in a small open economy,

$$\hat{v} = \left(1 - \omega\frac{\xi_v - (\eta - \eta_s)\,\eta}{\xi_v^*}\right) \cdot \hat{\tau} > 0. \tag{29}$$

Proposition 3 still applies, i.e., an import tariff relaxes financing constraints due to a higher price and expands supply. The home country gains from a small tariff.

Since all shocks by assumption occur at home, foreign countries are only affected by a change in the common price v^*. Replacing v by v^* in Section 3 and noting $\tau^j = 0$ yields the adjustment in a foreign country j.[23]

Proposition 8 ***(Protection spillovers)*** *(a) Import protection reduces the world price v^* and thereby discourages foreign investments I_c^j and I_u^j as well as innovation by raising the cut-off values q^j, and reduces (magnifies) foreign trade surpluses (deficits). (b) Domestic protection tightens foreign financing constraints. Welfare of foreign export nations ($\eta < \eta_s$) strongly falls since the negative terms of trade effect is reinforced by tightening financing constraints. Welfare of foreign import nations ($\eta > \eta_s$) changes ambiguously since the positive terms of trade effect may be offset by firms becoming more constrained.*

The interplay between welfare effects from terms of trade changes and financial frictions can generate interesting results on world welfare that would not be possible if firm-level investment were first-best in all countries. One interesting possibility is:

[23] International welfare results from protection are similar to Egger and Keuschnigg (2011). That paper did not consider an explicit innovation decision and the coexistence of constrained and unconstrained firms. Further, the analysis of R&D subsidies and financial development is new in the present paper.

Proposition 9 ***(World welfare)*** *If (i) all countries are close to autarky and terms of trade effects are small, and if (ii) the home economy is finance constrained while foreign economies are not, domestic protection raises world welfare.*

With terms of trade effects being small and foreign countries free of financial frictions, they will not experience any welfare change. For the home economy, Proposition 3 applies. Being financially constrained, it benefits from a strictly positive welfare gain since the policy boosts investment with an above normal rate of return. Since the home country gains while no foreign economy looses in this scenario, world welfare rises.

5.2 R&D Subsidies

Instead of protection, the home economy could subsidize R&D to become more competitive in the innovative industry. Intuition is that an R&D subsidy targets financing constraints more directly than protection. In expanding the innovative sector, it drives down the world price, leading to terms of trade effects on foreign economies that are favorable or unfavorable depending on their trade balance. A lower world price, however, tightens financing constraints in all foreign economies and thereby reduces their welfare. The price erosion also feeds back negatively on domestic equilibrium, irrespective of whether the country is a net exporter or importer, and reduces the possible welfare gains. Given (28) and the results of Section 3, we can state:

Proposition 10 ***(R&D subsidy in a large country)*** *(a) An R&D subsidy boosts aggregate supply, reduces the world price of innovative goods, and leads to a negative feedback effect on the domestic economy. Investment of unconstrained firms falls. Compared to a small open economy, the increase in constrained firm investment, innovation, aggregate supply and welfare are smaller. (b) The reduction in the world price reduces firm-level investments, innovation and trade surpluses in foreign economies. Welfare in foreign export nations strongly falls due to a tightening of financing constraints and a deterioration of terms of trade while welfare changes in foreign import nations are ambiguous.*

It is unlikely that the negative feedback could overturn the direct effects of an R&D subsidy as they obtain in a small open economy. Obviously, the smaller the share ω of the home economy in world GDP, the smaller is the impact on the world price v^*, and the smaller is the negative feedback. The feedback effect of a declining output price is strongest in the closed economy. If we can show the welfare gain to be positive in a closed country, it will a fortiori be positive in an open economy since the negative feedback is weaker. In Appendix C, we give a condition such that the qualitative results of the small open economy continue to hold in a closed economy. The condition is that the supply effect from induced innovation is not too strong, i.e., not too many firms switch from non-innovative, low volume producers to innovative, high volume producers.

5.3 Financial Development

More effective monitoring and better oversight of firms boosts the debt capacity of innovative firms which face the tightest constraint in raising outside funds. Financial development thus triggers a supply side expansion and drives down the world price by $\hat{v}^* = -(\omega\xi_m/\xi_v^*)\,\hat{m}$, see (28). The lower price reduces investment and output of non-innovative firms and constrains the expansion of innovative companies. The beneficial effects are thus scaled down.

Proposition 11 ***(Financial development in a large country)*** *(a) The reduction in the world price dampens the supply-side expansion. Investment and profits of unconstrained firms fall. Compared to a small open economy, the increase in constrained firm investment and profit is smaller, implying a smaller gain in innovation and welfare, and a smaller reduction of the trade deficit in innovative goods. (b) The lower world price reduces firm-level investments, innovation and trade surpluses in foreign economies. Welfare in foreign export nations strongly falls due to tighter financing constraints and deteriorating terms of trade while welfare changes ambiguously in foreign import nations.*

In Appendix D, we give conditions such that the qualitative results reported for the small open economy continue to hold in a closed economy. So they must hold a fortiori in large open economies where the negative feedback effect is weaker.

6 Conclusions

To investigate the interaction between innovation, finance and trade, we have proposed a multi-country, two-sector model with capital and sector specific labor. A discrete R&D decision splits firms into innovative and conservative ones. Conservative firms are unconstrained and invest at low scale until the rate of return is equal to the cost of capital. Given prior R&D spending, innovative firms are left with little own assets, are highly productive and could invest at a large scale in the subsequent expansion stage but are credit rationed. These assumptions reflect the stylized fact that more innovative and (in terms of own assets) smaller firms, have greater difficulty in raising external funds than others. With investment being restricted, innovative firms earn an excess return on capital and have unexploited investment opportunities. The credit constraint is partly relaxed by specialized intermediaries which actively monitor and supervise firms, thereby strengthen debt capacity and allow them to profitably invest at a larger scale.

Using this framework, we investigate the role of three alternative policies which affect financial frictions in distinct ways. These instruments are *tariff protection of the innovative sector*, *R&D subsidization*, and *financial sector development*. While all three policies reduce financial frictions and yield welfare gains at home, the consequences on foreign welfare are less clear-cut and depend on the specific interaction of terms of trade effects and financial frictions. The reduction in the world price strongly hurts foreign export nations, not only because of a negative terms of trade effect, but also because a lower price tightens financing constraints. Welfare in foreign import countries changes ambiguously since terms of trade and financial frictions work in opposite ways.

Appendix

A. Financial Contract Appendix A derives the solution of Section 4.3 from optimization. Suppose monitoring capital is scarce and earns a rent $\pi_c^m \geq \rho^m D_c^m$. The entrepreneur's surplus is reduced by the rents monitoring investors, $\pi^e = \pi - \pi^m$. Section 4.3 refers to the limit $\rho^m \to 0$ with perfect competition and free entry.

Banks compete by offering contracts i^m, D_c^m, i and I_c that maximize the entrepreneurs' surplus subject to incentive and participation constraints and $D_c = I_c - A_c - D_c^m$. Noting $y_c^e = I_c + vx_c - (1+i) D_c - (1+i^m) D_c^m$ together with $\pi_c^m \geq \rho^m D_c^m$, the program is

$$\begin{aligned} \pounds \;=\; & \max_{i, i^m, D_c^m, I_c} \; py_c^e - RA_c + \mu^e \left[py_c^e - \beta_c I_c\right] + \mu^m \left[p\left(1+i^m\right) D_c^m - \gamma I_c\right] \\ & + \lambda^b \left[p(1+i) - R\right] D_c + \lambda^m \left[p\left(1+i^m\right) D_c^m - \left(R+\rho^m\right) D_c^m - cI_c\right]. \end{aligned} \tag{A.1}$$

The necessary conditions are

$$\begin{aligned} 0 &= -\left(1+\mu^e-\lambda^b\right) pD_c, \quad 0 = -\left(1+\mu^e-\mu^m-\lambda^m\right) pD_c^m, \\ 0 &= -\left(1+\mu^e\right) p\left(i^m - i\right) + \left(\mu^m+\lambda^m\right) p\left(1+i^m\right) - \lambda^m\left(R+\rho^m\right) - \lambda^b\left[p(1+i) - R\right], \\ 0 &= \left(1+\mu^e\right) p\left(vx_c' - i\right) - \mu^e\beta_c - \mu^m\gamma + \lambda^b\left[p(1+i) - R\right] - \lambda^m c. \end{aligned}$$

The first and second conditions imply $\mu^m + \lambda^m = 1 + \mu^e = \lambda^b$. The third one requires $\lambda^m\left(R+\rho^m\right) = \lambda^b R$ so that $\lambda^b \geq \lambda^m \Leftrightarrow \rho^m \geq 0$. This, in turn, implies $\mu^m \geq 0$. Banks maximize π^e until their participation constraint binds, $p(1+i) = R$ and $\lambda^b > 0$. Use these relations to replace shadow prices in the last condition and get

$$\lambda^b = \frac{\beta_c}{\beta_c - \rho + (\gamma - c)\,\rho^m / \left(R+\rho^m\right)}, \quad \rho \equiv p\left(vx_c' - i\right) - c > 0. \tag{A.2}$$

A small rent ($\rho^m \to 0$) implies $\lambda^b \to \beta_c / \left(\beta_c - \rho\right) > 1$ and $\mu^e = \lambda^b - 1 > 0$. Hence, all shadow prices are positive and all constraints are binding which yields

$$p(1+i) = R, \quad p\left(1+i^m\right) D_c^m = \gamma I_c, \quad D_c^m = \delta^m I_c, \quad \delta^m \equiv (\gamma - c) / \left(R+\rho^m\right). \tag{A.3}$$

A share δ^m of assets is monitored funds. Finally, investment follows from $py_c^e = \beta_c I_c$,

$$IC^e: \quad \pi_c^e = \pi_c - \pi_c^m = p\left(vx_c - iI_c\right) - \left(c + \rho^m\delta^m\right) I_c = \beta_c I_c - RA_c. \tag{A.4}$$

The limiting case $\rho^m \to 0$ implies $\pi_c^m = \rho^m D_c^m = 0$, leading to (8) in the main text.

B. Financial Structure To prove Proposition 7**,** note $D_M \equiv s_c D_c^m$ and $D_E \equiv s_u D_u + s_c\left(D_c + D_c^m\right)$. Given identities $D_u = I_u - A$ and $D_c + D_c^m = I_c + (1-\sigma)\,k - A$, and noting $ds_c = -ds_u$, we have $dD_E = s_u dI_u + s_c dI_c - s_c k d\sigma + \left(D_c + D_c^m - D_u\right) ds_c$. Further manipulation yields

$$\hat{D}_M = \hat{I}_c + \hat{s}_c, \quad \hat{D}_E = \frac{s_u I_u}{D_E}\hat{I}_u + \frac{s_c I_c}{D_E}\hat{I}_c - \frac{s_c k}{D_E}\hat{\sigma} + \frac{s_c\left(D_c + D_c^m - D_u\right)}{D_E}\hat{s}_c. \tag{B.1}$$

Using the definition of $D_E = s_u D_u + s_c\left(D_c + D_c^m\right)$, the ratio D_M/D_E changes by

$$\hat{D}_M - \hat{D}_E = \left(1 - \frac{s_c I_c}{D_E}\right)\cdot \hat{I}_c - \frac{s_u I_u}{D_E}\cdot \hat{I}_u + \frac{s_c k}{D_E}\cdot\hat{\sigma} + \frac{(s_c + s_u)\,D_u}{D_E}\cdot \hat{s}_c. \tag{B.2}$$

We must distinguish a selection (via $\hat{s}_c$) and a scale effect (via $\hat{I}_j$). By the *selection effect*, all shocks raise the share of active relative to total lending, D_M/D_E, since all boost innovation and thereby raise s_c.

The *scale effect* differs by the type of shock. Financial development and R&D subsidies boost investment and external financing of constrained, innovative firms only, $\hat{I}_c > 0$, $\hat{I}_u = 0$. Since only they demand monitored finance, the scale effect raises the ratio D_M/D_E if s_c is sufficiently small initially. Equivalently, the share of constrained firm investment in total investment must be small relative to the industry measure of financial dependence (average share of external funds in total investment), $s_c I_c < D_E \Leftrightarrow s_c I_c/I_E < D_E/I_E$. Even if this condition is not fulfilled, the selection effect may still dominate and raise the lending ratio as claimed in part (i) of Proposition 7**.** Tariff protection has ambiguous effects. Note $\hat{I}_u = \varepsilon\hat{\tau}$ and $\hat{I}_c = (\varepsilon + \phi_v)\,\hat{\tau}$ where $\phi_v \gtrless 0$ although $\varepsilon + \phi_v > 0$. Assuming that both types of firms have relatively similar investment elasticities, $\phi_v \approx 0$ and $\hat{I}_c \approx \hat{I}_u$, we compute a negative scale effect that tends to offset the selection effect,

$$\left(1 - \frac{s_c I_c}{D_E}\right)\cdot \hat{I}_c - \frac{s_u I_u}{D_E}\cdot \hat{I}_u = -\frac{s_u A + s_c\left(A - k\right)}{D_E}\cdot \hat{I}_c < 0. \tag{B.3}$$

Intuitively, only those shocks (R&D subsidies and financial development) which selectively favor constrained innovative firms, also raise the share of monitored lending in total industry lending (e.g. the share of venture capital in total industry lending).

C. R&D Subsidy in a Closed Economy In autarky, where $\eta = \eta_s$, an R&D subsidy reduces the equilibrium output price by $\hat{v} = -(\xi_\sigma/\xi_v) \cdot \hat{\sigma}$. Plugging into (27) yields $\hat{U} = \rho\eta_i\eta\left[(\varepsilon + \phi_v)\,\hat{v} + \phi_\sigma\hat{\sigma}\right]$ or

$$\hat{U} = \rho \cdot \eta_i\eta\Omega_\sigma/\xi_v \cdot \hat{\sigma}, \quad \Omega_\sigma \equiv \phi_\sigma\xi_v - (\varepsilon + \phi_v)\,\xi_\sigma. \tag{C.1}$$

Clearly, there is an ambiguous welfare effect that stems from the negative consequences of a falling output price on the financing constraint. Evaluating the coefficient, we find

$$\begin{aligned}
\Omega_\sigma &\equiv \phi_\sigma\left[(1-\eta) + \alpha\varepsilon\frac{s_u x_u}{x_E}\right]\eta - \Gamma \cdot \frac{x_c - x_u}{x_E}q^2 g\,(q)\,\eta, \\
\Gamma &\equiv (\varepsilon + \phi_v)\,\mu_\sigma - \mu_v\phi_\sigma = \left[(1-q)\,x_c + qx_u\right]\frac{pv}{\delta I_c} > 0,
\end{aligned}$$

where the last equality uses $q = kR/(\pi_c - \pi_u)$. The coefficient Ω_σ is positive if $\frac{x_c - x_u}{x_E}q^2 g\,(q)$ is small, i.e., if the subsidy moves only a few firms ($ds_c = -ds_u = -qg\,(q)\,dq$) from the unconstrained to the constrained regime.

The falling price also offsets the direct effect of the subsidy on constrained investment. Substituting the equilibrium price change into $\hat{I}_c = (\varepsilon + \phi_v) \cdot \hat{v} + \phi_\sigma \cdot \hat{\sigma}$ yields

$$\hat{I}_c = \Omega_\sigma/\xi_v \cdot \hat{\sigma}, \tag{C.2}$$

where Ω_σ is given in (C.1) and is positive under the same conditions.

Finally, by (21), the extensive innovation margin in a closed economy changes by

$$\hat{q} = -\mu_v \cdot \hat{v} - \mu_\sigma \cdot \hat{\sigma} = -\frac{\Omega_q}{\xi_v} \cdot \hat{\sigma}, \quad \Omega_q \equiv \mu_\sigma\xi_v - \mu_v\xi_\sigma > 0. \tag{C.3}$$

Noting $\Gamma = (\varepsilon + \phi_v)\,\mu_\sigma - \mu_v\phi_\sigma$ from above yields

$$\begin{aligned}
\Omega_q &= \mu_\sigma\left[(1-\eta) + \alpha\left(\varepsilon + \phi_v\frac{s_c x_c}{x_E}\right)\right]\eta - \alpha\frac{s_c x_c}{x_E}\phi_\sigma\mu_v\eta - \rho\eta\eta_i \cdot \eta\Gamma, \\
\Omega_q &= \mu_\sigma\left[(1-\eta) + \varepsilon\alpha\frac{s_u x_u}{x_E}\right]\eta + \left(\alpha\frac{s_c x_c}{x_E} - \rho\eta\eta_i\right) \cdot \eta\Gamma > 0,
\end{aligned}$$

where the second line follows upon expanding ϕ_v in the first square bracket to $\phi_v + \varepsilon - \varepsilon$. Since $\alpha\frac{s_c x_c}{x_E} > \rho\eta\eta_i$ as noted subsequent to (26), an R&D subsidy clearly boosts innovation in a closed economy as well.

D. Financial Development in a Closed Economy: In autarky, the price reduction is $\hat{v} = -(\xi_m/\xi_v)\hat{m}$. Plugging into (27) yields $\hat{U} = \rho\eta_i\eta_s[(\varepsilon+\phi_v)\hat{v} + \phi_m\hat{m}]$ or

$$\hat{U} = \rho \cdot \eta_i\eta_s\Omega_m/\xi_v \cdot \hat{m} > 0, \quad \Omega_m \equiv \phi_m\xi_v - (\varepsilon+\phi_v)\xi_m > 0. \tag{D.1}$$

By rewriting the coefficient Ω_m, we can show it to be positive,

$$\begin{aligned}
\Omega_m &= \phi_m\left[(1-\eta_s) + \varepsilon\alpha\frac{s_u x_u}{x_E}\right]\eta + \eta\Gamma_m \cdot \frac{x_c - x_u}{x_E}q^2 g(q) > 0, \\
\Gamma_m &\equiv \phi_m\mu_v - (\varepsilon+\phi_v)\mu_m = \frac{pv(x_c - x_u)}{\pi_c - \pi_u}\phi_m > 0.
\end{aligned}$$

Clearly, financial development boosts welfare in a closed economy.

Constrained investment changes by $\hat{I}_c = (\varepsilon+\phi_v)\hat{v} + \phi_m\hat{m}$. Substituting the equilibrium price cut leaves a net positive investment stimulus in the closed economy,

$$\hat{I}_c = (\Omega_m/\xi_v)\cdot\hat{m}. \tag{D.2}$$

The innovation threshold in (21) changes by $\hat{q} = -\mu_v\hat{v} - \mu_m\hat{m}$, which gives

$$\hat{q} = -\Omega/\xi_v \cdot \hat{m}, \quad \Omega \equiv \mu_m\xi_v - \mu_v\xi_m. \tag{D.3}$$

To sign of Ω, note $\Gamma_m > 0$, expand ϕ_v to $\phi_v + \varepsilon - \varepsilon$ and collect terms involving Γ_m,

$$\Omega = \mu_m\left[(1-\eta) + \varepsilon\alpha\frac{s_u x_u}{x_E}\right]\eta - \eta\Gamma_m \cdot \left[\alpha\frac{s_c x_c}{x_E} - \rho\eta\eta_i\right],$$

where the term $\frac{s_c x_c}{x_E}\alpha - \rho\eta\eta_i$ is positive by the result noted after (26). So, in principle, financial development affects innovation ambiguously since Γ_m is positive. In an open economy, the feedback via the declining output price is scaled down, so that innovation must be encouraged if the economy's weight in the world economy is not too large.

References

[1] Aghion, Philippe, Thibault Fally and Stefano Scarpetta (2007), Credit Constraints as a Barrier to the Entry and Post-Entry Growth of Firms, *Economic Policy* 22, 731-779.

[2] Antràs, Pol and Ricardo J. Caballero (2009), Trade and Capital Flows: A Financial Frictions Perspective, *Journal of Political Economy* 117, 701-744.

[3] Antràs, Pol, Mihir A. Desai and Fritz C. Foley (2009), Multinational Firms, FDI Flows and Imperfect Capital Markets, *Quarterly Journal of Economics* 124, 1171-1219.

[4] Baldwin, Richard E. (1989), Exporting the Capital Markets: Comparative Advantage and Capital Market Imperfections, in: David B. Audretsch, Leo Sleuwaegen,and Hideki Yamawaki (eds.), *The Convergence of International and Domestic Markets*, Amsterdam: North Holland, 135-152.

[5] Beck, Thorsten (2002), Financial Development and International Trade: Is There A Link?, *Journal of International Economics* 57, 107-131.

[6] Beck, Thorsten (2003), Financial Dependence and International Trade, *Review of International Economics* 11, 296-316.

[7] Beck, Thorsten, Asli Demirgüç-Kunt, and Vojislav Maksimovic (2005), Financial and Legal Constraints to Growth: Does Firm Size Matter?, *Journal of Finance* 60, 137-177.

[8] Beck, Thorsten, Asli Demirgüç-Kunt, and Vojislav Maksimovic (2008), Financing Patterns Around the World: Are Small Firms Different?, *Journal of Financial Economics* 89, 467-487.

[9] Bloom, Nick, Rachel Griffith, and John Van Reenen (2002), Do R&D Tax Credits Work? Evidence from a Panel of Countries 1979-1997, *Journal of Public Economics* 85, 1-31.

[10] Bottazzi, Laura, Marco Da Rin and Thomas Hellmann (2008), Who Are the Active Investors? Evidence from Venture Capital, *Journal of Financial Economics* 89, 488-512.

[11] Brown, James R. and Bruce C. Petersen (2009), Why Has the Investment-Cash Flow Sensitivity Declined so Sharply? Rising R&D and Equity Market Developments, *Journal of Banking and Finance* 33, 971-984.

[12] Brown, Martin, Steven Ongena, Alexander Popov, and Pinar Yeşin (2011), Who Needs Credit and Who Gets Credit in Eastern Europe, *Economic Policy* 26, 93-130.

[13] Calomiris, Charles W. and R. Glenn Hubbard (1995), Internal Finance and Investment: Evidence from the Undistributed Profits Tax of 1936-37, *Journal of Business* 68, 443-482.

[14] Carpenter, Robert E. and Bruce C. Petersen (2002), Is the Growth of Small Firms Constrained by Internal Finance?, *Review of Economics and Statistics* 84, 298-309.

[15] Chirinko, Robert S. and Huntley Schaller (1995), Why Does Liquidity Matter in Investment Equations?, *Journal of Money, Credit and Banking* 27, 527-548.

[16] Chor, Davin, C. Fritz Foley, and Kalina Manova (2008), Host Country Financial Development and MNC Activity, unpublished manuscript, Harvard University.

[17] Clemhout, Simone and Henry Y. Wan (1970), Learning-by-doing and Infant-Industry Protection, *Review of Economic Studies* 37, 33-56.

[18] Corden, W. Max (1974), *Trade Policy and Economic Welfare*, Oxford: Clarendon Press.

[19] Do, Quy-Toan and Andrei A. Levchenko (2007), Comparative Advantage, Demand for External Finance, and Financial Development, *Journal of International Economics* 86, 796-834.

[20] Egger, Peter and Christian Keuschnigg (2011), *Corporate Finance and Comparative Advantage*, University of St. Gallen, www.alexandria.unisg.ch/Publikationen/51206.

[21] Fazzari, Steven M. and Bruce C. Petersen (1993), Working Capital and Fixed Investment: New Evidence on Financing Constraints, *Rand Journal of Economics* 24, 328-342.

[22] Fisman, Raymond and Inessa Love (2003), Trade Credit, Financial Intermediary Development, and Industry Growth, *Journal of Finance* 58, 353-374.

[23] Gompers, Paul A. and Josh Lerner (2001), *The Money of Invention. How Venture Capital Creates New Wealth*, Boston: Harvard Business School Press.

[24] Gorodnichenko, Yuriy and Monika Schnitzer (2010), *Financial Constraints and Innovation: Why Poor Countries Don't Catch Up*, CEPR DP 7721.

[25] Grossman, Gene M. and Elhanan E. Helpman (1991), *Innovation and Growth in the Global Economy*, MIT Press: Cambridge, MA.

[26] Grossman, Gene M. and Henrik Horn (1988), Infant-Industry Protection Reconsidered: The Case of Informational Barriers to Entry, *Quarterly Journal of Economics* 103, 767-787.

[27] Guiso, Luigi (1998), High-tech Firms and Credit Rationing, *Journal of Economic Behavior & Organization* 35, 39-59.

[28] Hall, Bronwyn H. (2002), The Financing of Research and Development, *Oxford Review of Economic Policy* 18, 35-51.

[29] Hall, Bronwyn H. and Josh Lerner (2009), The Financing of R&D and Innovation, NBER WP 15325; forthcoming in: Hall, B. H. and N. Rosenberg (eds.), *Handbook of the Economics of Innovation*. Amsterdam: North-Holland.

[30] Hall, Bronwyn H. and John Van Reenen (2000), How Effective are Fiscal Incentives for R&D? A Review of the Evidence, *Research Policy* 29, 449-469.

[31] Himmelberg, Charles P. and Bruce C. Petersen (1994), R&D and Internal Finance: A Panel Study of Small Firms in High-tech Industries, *Review of Economics and Statistics* 76, 38-51.

[32] Holmstrom, Bengt and Jean Tirole (1997), Financial Intermediation, Loanable Funds, and the Real Sector, *Quarterly Journal of Economics* 62, 663-691.

[33] Hoshi, Takeo, Anil Kashyap, and David Scharfstein (1991), Corporate Structure, Liquidity, and Investment: Evidence from Japanese Industrial Groups, *Quarterly Journal of Economics* 106, 33-60.

[34] Hubbard, Glenn (1998), Capital Market Imperfections and Investment, *Journal of Economic Literature* 36, 193-225.

[35] Ju, Jiangdong and Shang-Jin Wei (2011), When is Quality of Financial System a Source of Comparative Advantage?, *Journal of International Economics*, forthcoming.

[36] Kaplan, Steven N. and Luigi Zingales (1997), Do Investment-Cash Flow Sensitivities Provide Useful Measures of Financing Constraints?, *Quarterly Journal of Economics* 112, 169-215.

[37] Kletzer, Kenneth and Pranab Bardhan (1987), Credit Markets and Patterns of International Trade, *Journal of Development Economics* 27, 57-70.

[38] Kortum, Samuel and Josh Lerner (2000), Assessing the Contribution of Venture Capital to Innovation, *RAND Journal of Economics* 31, 674-692.

[39] Manova, Kalina (2008a), Credit Constraints, Equity Market Liberalizations and International Trade, *Journal of International Economics* 76, 33-47.

[40] Manova, Kalina (2008b), *Credit Constraints, Heterogeneous Firms and International Trade*, NBER WP 14531.

[41] Mayer, Wolfgang (1984), The Infant-Export Industry Argument, *Canadian Journal of Economics* 17, 249-269.

[42] Rajan, Raghuram G. and Luigi G. Zingales (1998), Financial Dependence and Growth, *American Economic Review* 88, 559-586.

[43] Schaller, Huntley (1993), Asymmetric Information, Liquidity Constraints, and Canadian Investment, *Canadian Journal of Economics* 26, 552-574.

[44] Sorensen, Morten (2007), How Smart is Smart Money? A Two-Sided Matching Model of Venture Capital, *Journal of Finance* 62, 2725-2762.

[45] Svaleryd, Helena and Jonas Vlachos (2005), Financial Markets, the Pattern of Industrial Specialization and Comparative Advantage: Evidence from OECD Countries, *European Economic Review* 49, 113-144.

[46] Tirole, Jean (2006), *The Theory of Corporate Finance*, Princeton University Press.

[47] Tirole, Jean (2001), Corporate Governance, *Econometrica* 69, 1-35.

[48] Ughetto, Elisa (2008), Does Internal Finance Matter for R&D? New Evidence from a Panel of Italian Firms, *Cambridge Journal of Economics* 32, 907-925.

[49] Ughetto, Elisa (2009), Industrial Districts and Financial Constraints to Innovation, *International Review of Applied Economics* 23, 597-624.