CESifo Working Papers

www.cesifo.org/wp

Innovation, Trade, and Finance

Peter Egger
Christian Keuschnigg

CESIFO WORKING PAPER NO. 3529
CATEGORY 8: TRADE POLICY
JULY 2011

PRESENTED AT CESIFO AREA CONFERENCE ON GLOBAL ECONOMY, FEBRUARY 2011

An electronic version of the paper may be downloaded
- *from the SSRN website: www.SSRN.com*
- *from the RePEc website: www.RePEc.org*
- *from the CESifo website: www.CESifo-group.org/wp*

CESifo *Working Paper No. 3529*

Innovation, Trade, and Finance

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 necessary tangible continuation investments than non-innovating firms. As a result, they are financially constrained while standard 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 protection, 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-Code: F110, G320, L260, O380.

Keywords: innovation, financial development, R&D subsidies, protection.

Peter Egger
ETH Zurich / KOF
Weinbergstrasse 35
8092 Zurich
Switzerland
egger@kof.ethz.ch

Christian Keuschnigg
University of St. Gallen / FGN-HSG
Varnbuelstrasse 19
9000 St. Gallen
Switzerland
Christian.Keuschnigg@unisg.ch

June 9, 2011
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, 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 and the Institute for Advanced Studies in Vienna. In particular, we would like to thank Philippe Aghion, Simon Evenett, Thibault Fally, Holger Görg, and Evelyn Ribi 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) finance constraints in the presence of firms' discrete R&D decisions and their consequences for tangible investment, comparative advantage, and trade. We assume that finance 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 pledgable to outside investors. Hence, the level of pledgable 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. Modeling the banking sector as to be perfectly competitive, extra costs of monitoring have to be matched by associated extra benefits. More expensive credit from active banks is not suitable to all firms. However, 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 for investment. Then, passive and active financial intermediaries may coexist. The extra costs of monitoring imply a higher cost of capital when financing investment through credit from active banks. However, monitoring is productive in the sense that it reduces private benefits from managerial misbehavior. This entails a *certification function* of active financial 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 for an economy at large by incentivizing entrepreneurs, raising firms' debt capacity, and improving access to external credit. Altogether, this boosts firm value through the greater realization of productive investment opportunities. If monitoring helps exploiting otherwise unused investment opportunities with high returns of constrained firms sufficiently, 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 at a given marginal cost. As a consequence, a country whose financial sector develops will relax finance constraints, encourage innovation, and raise tangible investments and the value of constrained (innovative) firms.[2] In this way, financial sector 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 on the effects of finance on the real economy.

We consider countries with two sectors: a standard, non-innovative sector where firms display low productivity, have limited investment opportunities, 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

[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 VC is responsible for a disproportionately large share of overall industrial innovation in the U.S.

[2]Financial development is captured by monitoring technology parameters in our model. Of course, the amount of credit channeled through active banks is endogenous to those and other (e.g., product market) parameters. The model suggests that measuring financial development by the extent of credit administered by active banks may be misleading, since the demand for such credit on innovative firms' part inter alia depends on fundamental parameters which are unrelated to financial development.

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 of expansion investment. 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 it is constrained is endogenously determined by our model. Hence, the model determines the extensive and intensive margins of capital investments by and financial constraints of innovative firms.

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.[3] The key results are the following. First, in raising the domestic price and earnings per firm, *import protection* ceteris paribus raises profits and boosts the debt capacity of constrained firms. Import protection thereby relaxes finance constraints and allows innovative firms with an excess rate of return to invest at a larger scale. For this reason, in the presence of financial frictions to innovative firms with high tangible investment opportunities, a small level of protection can raise domestic welfare, provided that terms of trade effects in the importing country are small. 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 for infant industry protection in industrial economics 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

[3] 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 Ju and Wei (2008) and Antras and Caballero (2009) for considering financial frictions in economies which are open to goods trade and capital flows.

costs were lowered.[4] In our model, gains from protection arise from informational barriers between producers and financial intermediaries (rather than consumers).[5]

Second, *R&D subsidies* boost innovation and lead to welfare gains, not because of knowledge spillovers which are excluded in our model,[6] but because they increase own funds which, in turn, renders innovating firms ceteris paribus more successful in attracting external investors.[7] 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 finance 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

[4] In international economics, that argument has been 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 such protection depends on the nature and time structure of the information asymmetry between consumers and producers.

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

[6] R&D subsidies are widely discussed in the literature on endogenous growth as a means to reduce market failures associated with external economies to R&D. Grossman and Helpman (1991) discuss beneficial effects of R&D subsidies in situations where 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 which leads to underinvestment and an associated excess return on investment.

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

welfare gains at home, 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 negative terms of trade effects, but also because lower prices tighten finance constraints. In foreign import countries of innovative goods, a lower price of innovative goods yields positive terms of trade effects which tend to offset the negative consequences on financial frictions.

The novelty of the contributions of the present paper in comparison to earlier work on the effects of financial constraints on the real side of open economies may be summarized as follows. First, rather than treating financial constraints as an exogenous parameter, they emerge endogenously through a discrete innovation choice of heterogeneous firms and the associated tangible investment opportunities in combination with deep characteristics of the financial industry such as a co-existence of standard and active banks. The latter engage in monitoring and provide credit types of heterogeneous costs. Endogenous finance constraints affect the extensive and the intensive margin of constrained tangible investment in an economy as well as average productivity and R&D intensity in the innovative sector. The severeness of financing constraints depends inter alia on structural parameters of active financial intermediation. While active banking is more costly than standard banking, it brings about the aforementioned certification effect for entrepreneurs and R&D projects which leads to greater supply and, in turn, more demand for credit as a whole, from active as well as standard banks. However, a better monitoring technology reduces the costs of the certification effect so that the demand for active banking, and the volume of credit transmitted through active banks will rise endogenously in the model. Second, we analyze and compare three different policy instruments – 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 sector efficiency across countries as captured by the monitoring technology parameters of active financial intermediaries. 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 finance constraints – are well backed by empirical evidence. In what follows, we will summarize findings which surfaced in empirical work on the roots as well as the consequences of finance constraints.

In a seminal paper, Rajan and Zingales (1998) show that, at the macro level, poorly developed financial markets in a country 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 for their projects. 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).

In response to such financing constraints, firms conduct less investments than they would otherwise. Unlike in a Modigliani-Miller world without financing constraints, 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.[8]

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 standard sector produces the *numeraire* good with a Ricardian 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. The attention mainly focusses on the innovative sector which consists of heterogeneous firms, driven by entrepreneurs who make risky innovation and investment choices. We think of a firm as an entrepreneur managing one project. Production combines one unit of entrepreneurial labor and physical capital I, using a strictly concave technology $\theta f(I)$ where θ is total factor productivity as determined by discrete innovation choice. Entrepreneurs first decide on R&D intensity and subsequently choose the level of equip-

[8] Do and Levchenko (2007) present evidence that financial development depends on trade patterns and argue that financial development is endogenous and in part determined by the demand for external financing which 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). Very recent work indicates that limited access to external credit through weak investor protection even reduces foreign direct investment, production, and trade of multinational companies (see Chor, Foley, and Manova, 2008; Antras, Desai and Foley, 2009), and alters the decision to deploy technology through foreign direct investment as opposed to arm's length technology transfers. However, the latter lies beyond the scope of this paper.

ment 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 $\theta = 1$. Both activities are risky. R&D is successful with probability q'. Conditional on surviving the R&D stage, capital 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 expansion investment stage.

Entrepreneurs are heterogeneous with respect to their innate ability to innovate, characterized 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 sequence of decisions and events is: (i) Given project type q', they 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. Private R&D cost may be reduced by a proportional subsidy σ. (ii) When surviving the early stage, firms choose capital investment I_j and apply for credit $I_j - A_j$, possibly from different sources. (iii) Given investment, 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 and constrained in the expansion stage. Firms with less potential abstain from R&D, have undiminished own resources, are less productive, have few growth opportunities and, by assumption, will be financially unconstrained. Let the subindex $j = c$ refer to constrained, R&D intensive firms and u to unconstrained firms with little (zero) R&D spending. Conditional on their innovation strategy, firms expect profits $\pi_c > \pi_u$ from subsequent expansion investment.

Ex ante, the expected profit of starting a firm is

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

Capital and labor endowments are distributed among risk-neutral agents. 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 country also hosts a unitary mass of wealthy individuals endowed with assets A per capita. A *fixed* fraction E has entrepreneurial ability, the others do not. Part $1-E$ can invest wealth either in deposits paying a safe interest r ($R = 1+r$) or in a standard linear investment technology. Entrepreneurs run a firm in the innovative sector and earn an expected surplus π_E on top of AR. However, when the business fails, all assets are lost and income drops to zero. Given an expected rent π_E, all E agents with entrepreneurial ability indeed prefer investing in their own firm rather than the capital market.

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. 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. An entrepreneur's expected profit π_j^e, equal to the surplus over residual own assets, amounts to

$$\begin{aligned} \pi_j^e &= p\left[I_j + vx_j - (1+i)D_j - (1+i^m)D_j^m\right] - RA_j, \\ \pi_j^m &= p(1+i^m)D_j^m - RD_j^m - c^m I_j = 0, \\ \pi_j^b &= p(1+i)D_j - RD_j = 0, \\ \pi_j &= p(I_j + vx_j) - c^m I_j - RI_j. \end{aligned} \quad (2)$$

Active banks incur monitoring costs $c^m I_j$, measured in terms of labor or numeraire output. Given zero profits of competitive intermediaries, entrepreneurs extract the full surplus

$\pi_j^e = \pi_j$. Competition fixes the interest rate $i > r$ on standard business loans and yields a convenient form of expected profit,

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

3.2 Unconstrained Investment

We first turn to the case of standard firms with little need for external funds. Given Assumption 1 below, we show that these firms are unconstrained, are able to 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 and the entrepreneur obtains residual earnings $y_u^e \equiv I_u + vx_u - (1+i) D_u$. Once the firm has determined investment and raised external funds, it 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, thus, expected income is 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 is fulfilled,

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

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 state, managerial effort is contractible and monitoring is not required so that monitoring costs are absent. The first-best level of investment maximizes expected profit $\pi_u^e = \pi_u$ in (3) with $c^m = 0$. 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, see the lower part of Figure 1. Banks are willing to lend the entire desired loan. The firm is financially unconstrained and relies exclusively on passive bank financing without monitoring. Monitoring capital would only 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 finance constrained. To relax the constraint and further exploit their investment opportunities, these firms might want to demand monitored finance in addition to standard bank credit. Assumption 2 below implies that this is a value-increasing strategy in spite of monitoring capital being more expensive than passive bank financing. Active banks must also cover monitoring cost in addition to the same refinancing cost R per dollar of credit. Being more expensive, firms will resort to monitoring capital 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 applies for monitored finance in addition to standard bank credit. We then show, given Assumption 2, that mixed financing indeed yields higher value than passive bank credit alone.

As before, we solve by backward induction. In the effort stage, investment and financial contracts are already determined. Monitoring and passive banks are promised repayment 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 are contractible, leading to a double moral hazard problem. Both efforts are either high or low. As before, high managerial effort raises the success probability to $p > p_L$ while monitoring reduces private benefits, giving bI_c if the entrepreneur is monitored, and BI_c if she is not,

$b < B$. Monitoring thus makes shirking less rewarding. Profit shares determine whether rewards are large enough to motivate high monitoring and managerial effort. With active monitoring, managerial effort is high if

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

The monitoring 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 $c^m I_c$, leading to expected earnings equal to $p_L y_c^m + c^m I_c$. 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 pledgable income and improves access to external funds.

In stage (ii), the firm chooses investment and offers contracts to attract both types of external funds. The contracts must satisfy both incentive constraints and allow external investors to break even. Given the higher cost, the firm raises as little active capital as possible to incentivize monitoring and sets a *minimum* repayment $y_c^m = \gamma I_c$ such that the monitor's incentive constraint just binds. Given this repayment, the firm extracts rents by demanding more funds D_c^m until the participation constraint binds,

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

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 income $y_c^e \geq \beta_c I_c$ which is lower with monitoring than without. Hence, $\beta_c < \beta_u \equiv B/(p - p_L)$

since $b < B$. Both incentive compatible income stakes limit the amount of repayment that can be pledged to passive banks. Hence, the firm's residual debt capacity is restricted by $(1+i) D_c \leq I_c + vx_c - \gamma I_c - \beta_c I_c$ 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 as in (7). The remaining credit raised from standard banks which supply $D_c = I_c - A_c - D_c^m$. Substituting this into the debt capacity, multiplying by p, using $p(1+i) = R$, and substituting D_c^m from (7) yields

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

If this financing constraint binds, it implicitly determines investment.

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

Figure 1 illustrates how investment is determined. The left-hand side of equation (8) is the expected profit and corresponds to the upper hump-shaped curve. Its maximum gives the virtual unconstrained investment of an innovative firm where no excess return is earned, $vx_c' = i$. The right-hand side of (8) is the 'incentive-line' starting out from the intercept $-A_c R$. The intersection of these two lines determines the constrained investment level as in (8). At this point, the slopes satisfy $p\beta_c > p(vx_c' - i) - c^m > 0$. 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.[9] Taking the differential of (3), we can thus state:

[9] If firms asked for a marginally larger credit, incentive constraints would be violated, i.e., firms and monitors would shirk and monitoring capital would not be used. Passive banks could still provide credit by discretely raising the loan rate to $i_L > i$ until $(1+i_L) p = R$. Profit v_c^e would discretely fall due to the rise in the loan rate i_L and the loss in the value-enhancing contribution of monitoring. We must assume p_L low enough to exclude this case. An equilibrium with shirking is definitely not viable if $p_L \to 0$.

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

Knowing investment yields the amount of monitoring capital D_c^m in (7) and standard debt $D_c = I_c - A_c - D_c^m$ which is residually obtained from passive banks.

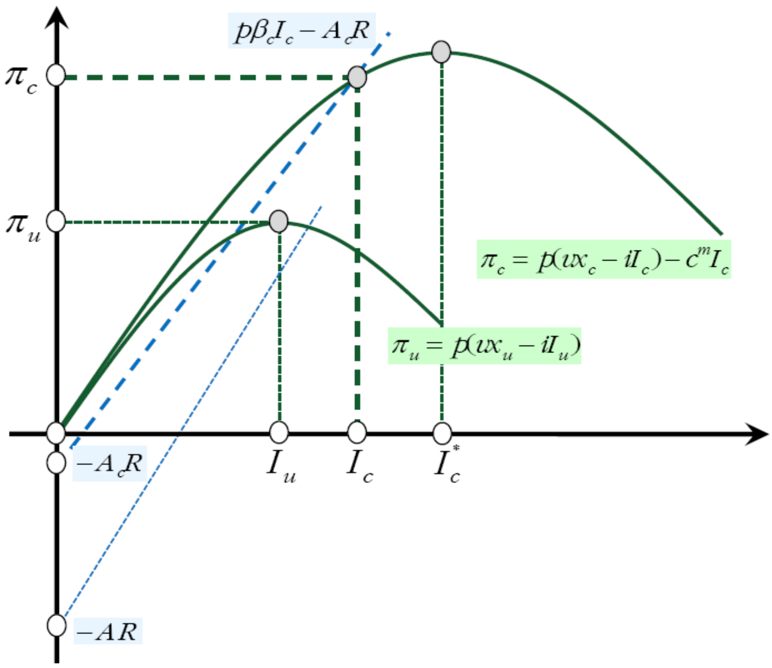

Fig. 1: Constrained and Unconstrained Firm Performance

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 were no monitoring, private benefits would be high with $\beta_c = \beta_u$, i.e., the incentive lines would be parallel. Monitoring constrains private benefits with $\beta_c < \beta_u$ and, thus, rotates the incentive line of the constrained firm clockwise. In relaxing the finance 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 finance constraint are larger than the cost of monitoring. More formally, we start in the absence of monitoring where $b = B$

and $c^m = 0$ and consider an introduction and marginal further increase of monitoring intensity m, creating costs $dc^m/dm > 0$ 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), $d\pi_c = \rho dI_c - I_c dc^m$. Monitoring adds extra costs $I_c dc^m$, 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 pledgable income by reducing private benefits. Clearly, if the firm is severely constrained and excess return is large, the additional investment substantially augments profits by ρdI_c which may be worth more than the extra cost $I_c dc^m$. Demand for monitoring capital exists if the following assumption on 'monitoring productivity' is imposed:

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

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

The assumption means that engaging active investors and introducing a small amount of monitoring activity boosts the firm's net present value. To show this, we define the relative increase in marginal monitoring cost by[10] $\hat{c}_m \equiv dc^m/\left(p\beta_c\right)$, and of monitoring intensity by $\hat{m} \equiv dm/\left(p\beta_c\right)$. 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, incentive compatible entrepreneurial compensation. Monitoring thereby raises pledgable income and boosts investment. Using $\hat{\sigma} \equiv d\sigma/\left(1-\sigma\right)$, the differential of the investment condition (8) gives

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

where $R > \delta$ assures positive leverage, i.e., $dI_c/dA_c = R/\delta > 1$. Given benefits and costs, monitoring ($\hat{m} = \hat{c}^m$) is desirable only if the net impact on expected profit is positive,

[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.

i.e., $d\pi_c = \rho dI_c - I_c dc^m > 0$. Using $\hat{c}^m = \hat{m}$ and δ,

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

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 do not earn any excess return, they do not benefit from and do not demand monitoring capital since it would only add to costs. (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^m. 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 are heavily reliant on external funds. Being constrained, they benefit from monitoring which improves access to capital and allows them to invest more. Since active finance is more costly, firms raise only the minimum amount necessary to guarantee monitoring, and obtain the remaining credit from standard banks. 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] Standard, less innovative firms have relatively large

[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

own assets and few investment opportunities. They are thus able to finance the first-best investment level and earn no more than the normal return on capital.

Figure 1 compares investment and profit of constrained and unconstrained firms. If innovative firms had more own funds and if agency costs were smaller, they could invest the first-best level of capital. Due to higher productivity, virtual investment and profit would clearly be larger than for standard firms. As illustrated in Figure 1, we impose parameter restrictions such that the finance constraint becomes binding and represses investment and profit but only to an extent such that innovative firms invest at a larger scale and earn larger profits than standard firms, $I_c > I_u$ and $\pi_c > \pi_u$.

3.4 R&D Choice

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

$$q = (1-\sigma)kR/(\pi_c - \pi_u). \tag{9}$$

Figure 2 illustrates how discrete innovation choice splits the entrepreneurial sector into innovative and standard firms. Types $q' < q$ strictly prefer to avoid R&D spending while types $q' > q$ invest in R&D which turns them into highly productive growth companies.

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

$$s_c = \int_q^1 q' dG(q'), \quad s_u = \int_0^q q' dG(q'), \quad s_k = \int_q^1 dG(q'). \tag{10}$$

restriction determining the existence of a market for informed capital. In the first-best benchmark, a market for monitoring capital no longer exists.

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

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

$$\pi_E = s_u \pi_u + s_c \pi_c - (1 - \sigma) kR s_k > 0. \tag{11}$$

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 $q' > q$.

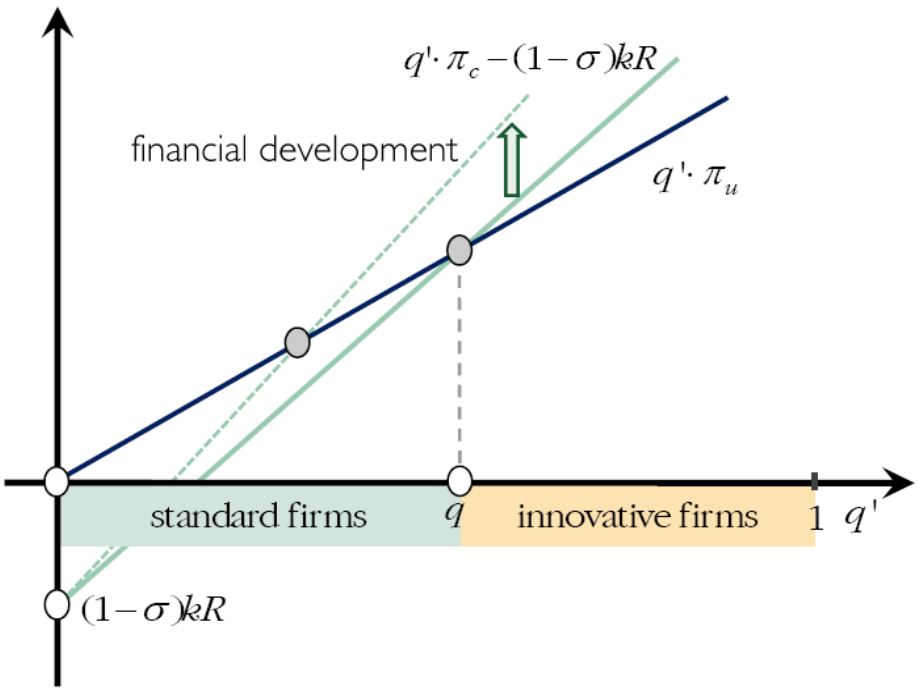

Fig. 2: R&D Choice

The R&D choice naturally dichotomizes innovative sector firms into cash-poor growth companies and cash-rich, but less productive standard 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. Furthermore, early stage R&D

endogenizes the fraction of constrained firms in the innovative sector. Hence, finance constraints operate on the extensive and intensive margins of business investment.

3.5 General Equilibrium

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

$$u_i = \max_{c_{iN}, c_{iE}} u\left(c_{iN}, c_{iE}\right) + B_i \quad s.t. \quad c_{iN} + v c_{iE} \leqslant y_i. \tag{12}$$

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 standard 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

$$A = Z + K \cdot E, \quad K \equiv s_k k + \bar{I}, \quad \bar{I} \equiv \textstyle\sum_j s_j I_j, \tag{13}$$

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

At the end of the period, the government collects a per-capita tax T 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. The fiscal budget is

$$TL = \sigma k \cdot s_k E R. \tag{14}$$

Depending on occupational activity and on success and failure in entrepreneurship, a specific person i may have quite different income. Workers are subject to a lump-sum tax T, giving income $y_L = 1 - T$ per capita. Investors earn $y_I = AR$ independent of asset allocation. Entrepreneurial talent being scarce, entrepreneurs obtain positive rents on average, $y_E = AR + \pi_E$. Total income is $Y = \pi_E E + AR + y_L L$. Define average values by $\bar{x} \equiv \sum_j s_j x_j$, and similarly for $\bar{I}$. Substituting π_E and π_j, the fiscal constraint yields aggregate income $Y = \left[\left(\bar{I} + v\bar{x}\right) p - \bar{I}R - c^m I_c s_c - kRs_k\right] E + AR + L$, where $c^m I_c$ is the resource cost of monitoring per innovative firm which reduces sector 2 output. Use now the capital market condition (13), define sectoral outputs X_E and X_N, and note the consumer budget in (12) to obtain the income expenditure identity,

$$C_N + vC_E = Y = vX_E + X_N, \quad X_E \equiv \bar{x}pE, \quad X_N \equiv L + ZR + \bar{I}pE - c^m s_c I_c E. \tag{15}$$

The trade balance condition in open economies is $(C_N - X_N) + v\,(C_E - X_E) = 0$.

Arbitrage and linearity of the Ricardian investment technology fixes the deposit factor R and the loan rate i by (3). Innovative sector investment $\bar{I}$ is determined by interest rates and a world relative price v. Equilibrium in the loanable funds market thus residually determines investment Z in the standard sector. Innovation choice fixes the composition of firms in the entrepreneurial 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 standard goods. In a closed economy, v clears the innovative goods market $C_E = X_E$, implying market clearing in the standard sector as well.

4 Small Open Economy

In this section, 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. When analyzing import protection, we assume the country to be an importer of innovative goods.[13] Buyer arbitrage links domestic and foreign prices by $v = \tau v^*$ where $\tau \geqslant 1$ is a measure of non-tariff barriers. 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 $\hat{v} = \hat{\tau}$. When studying the R&D subsidy, we assume the initial equilibrium to be untaxed, i.e., $\sigma = T = 0$ at the outset.

4.1 Firm Level Adjustment

Standard and innovative 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. Using $x_j = \theta_j (I_j)^\alpha$,

$$\hat{I}_u = \varepsilon \cdot \hat{v}, \quad d\pi_u = pvx_u \cdot \hat{v}, \quad \varepsilon \equiv \frac{-x'(I_j)}{I_j x''(I_j)} = \frac{1}{1-\alpha}. \tag{16}$$

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

By way of contrast, constrained investment reflects a firm's debt capacity and is determined in (8). Investment is not driven by the user cost of capital but rather depends on the determinants of pledgable income, such as the level of monitoring and of 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 pledgable income. We interpret financial development as an increase in monitoring productivity of active banks, given a fixed marginal cost c^m. The investment response of

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

constrained firms is stated in equation (i) following (A2). To compare with the unconstrained case, we rewrite this condition as

$$\hat{I}_c = (\varepsilon + \phi_v) \cdot \hat{v} + \phi_\sigma \cdot \hat{\sigma} + \phi_m \cdot \hat{m}, \tag{17}$$

where coefficients are defined as

$$\phi_v \equiv \frac{vpx_c}{\delta I_c} - \varepsilon, \quad \phi_\sigma \equiv \frac{(1-\sigma)\, kR}{\delta I_c}, \quad \phi_m \equiv \frac{\lambda p \beta_c}{\delta}.$$

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

A higher price stimulates investment of constrained firms as well although the price elasticity is generally not the same. The mechanism, however, is entirely different. The stimulus comes from the increased cash-flow and not from the change in the user cost. Financial sector development in terms of higher monitoring productivity also raises the firm's pledgable income and debt capacity and thereby boosts investment by facilitating access to external credit. Since monitoring cannot play a useful role when firms are unconstrained, it does not affect standard firm investment. Finally, the R&D subsidy strengthens the firm's own equity after R&D spending, thereby relaxes the finance 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.

Unlike in the neoclassical case, constrained firms earn an excess return since they are unable to fully exploit investment opportunities. 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 finance constraint and boosting investment yields additional profit in proportion to the excess return ρ net of marginal monitoring cost.[14] Substituting the investment response gives

$$d\pi_c = [pvx_c + \rho I_c(\varepsilon + \phi_v)] \cdot \hat{v} + \rho I_c \phi_\sigma \cdot \hat{\sigma} + \rho I_c \phi_m \cdot \hat{m}. \tag{18}$$

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 finance 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. Evaluating the changes at the untaxed equilibrium with $\sigma = 0$, 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. In this case, the subsidy would shift up the profit line net of R&D cost of an innovative firm in Figure 2 (not drawn), leading to a lower innovation threshold. When firms are constrained, the subsidy additionally boosts investment and strengthens profits, thereby rotating the profit line to the left and inducing even more innovation. The figure also illustrates the effect of financial development on innovation. Since monitoring is useful only when firms are constrained, it cannot play a role in the first-best equilibrium. However, since a higher monitoring intensity 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 standard firms. As shown in Figure 3, 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 (17), we find a change in the cut-off probability equal to

$$\hat{q} = -\mu_v \cdot \hat{v} - \mu_\sigma \cdot \hat{\sigma} - \mu_m \cdot \hat{m}, \tag{19}$$

[14]Setting $\rho = 0$ recovers the unconstrained case. Firms would not want monitoring capital on top of passive bank credit so that $c^m = 0$. The impact on profit would be as in (16) since unrestricted investment drives down the excess return to zero. By the envelope theorem, a variation of investment does not affect profits of unconstrained firms with a normal return on capital.

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 high-productivity firms rises, and so does average productivity in the industry.[15] 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 (11) rises by $d\pi_E = s_u d\pi_u + s_c d\pi_c + kRs_k d\sigma + \left[\left(\pi_c - \pi_u\right) q - \left(1-\sigma\right) kR\right] ds_k$, where $\sigma = 0$ initially. The square bracket is zero by discrete R&D choice in (9). Noting $\bar{x} = \sum_j s_j x_j$, expected profit ex ante changes by

$$d\pi_E = \left[pv\bar{x} + \rho s_c I_c\left(\varepsilon + \phi_v\right)\right] \cdot \hat{v} + \left[s_k kR + \rho s_c I_c \phi_\sigma\right] \cdot \hat{\sigma} + \rho s_c I_c \phi_m \cdot \hat{m}. \tag{20}$$

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 $X_E = \bar{x}pE$ changes in proportion to $\bar{x} = s_c x_c + s_u x_u$ which is a measure of average output of innovative and standard 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 $d\bar{x} = s_c dx_c + s_u dx_u - \left(x_c - x_u\right) qg\left(q\right) dq$, or

$$\hat{X}_E = \zeta_{x,v} \cdot \hat{v} + \zeta_{x,\sigma} \cdot \hat{\sigma} + \zeta_{x,m} \cdot \hat{m}, \tag{21}$$

[15] Average productivity is $\theta_E = \frac{s_c}{s_c + s_u}\theta + \frac{s_u}{s_c + s_u}$. Since $s_c + s_u$ is a constant, innovation ($\hat{q} < 0$) raises average productivity in the industry by $d\theta_E = -\left(\theta - 1\right) \frac{q^2 g(q)}{s_c + s_u} \cdot \hat{q}$.

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

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

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 standard producer into a highly productive growth company, output 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, 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 $s_c x_c/\bar{x}$. In a first-best case, the subsidy does not affect investment and output on the intensive margin ($\phi_\sigma = 0$) 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 wage income of workers, $Y = AR + \pi_E E + (1 - T)\,L$. Using the fiscal constraint and starting from an untaxed equilibrium, it changes by $dY = Ed\pi_E - ks_k ERd\sigma$. Substituting the change in expected profits of a new firm in (20) yields

$$\hat{Y} = \left(\eta_s + \zeta_{y,v}\right)\cdot\hat{v} + \zeta_{y,\sigma}\cdot\hat{\sigma} + \zeta_{y,m}\cdot\hat{m}, \quad \eta_s \equiv \frac{vX_E}{Y}, \quad \eta_i \equiv \frac{s_c I_c}{vp\bar{x}}, \tag{22}$$

where η_s is the GDP share of the innovative sector and coefficients are defined as

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

We also use η_i for the share of constrained investment in the expected value of output per firm. Note how the excess return ρ magnifies income gains. In the first-best, $\rho = 0$

and $\hat{Y} = \eta_s \cdot \hat{v}$. The impact of R&D subsidies or financial development arises only via the effect on finance constraints. These policies thus help to implement additional investments with an above normal rate of return while the alternative use of resources in the standard sector, i.e., $Z = A - \left(s_k k + \bar{I}\right) E$ in (13), 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 (12), the demand allocation is $vC_E = \eta Y$. Using the change in national income in (21), this yields

$$\hat{C}_E = \hat{Y} - \hat{v} = -\left(1 - \eta_s - \zeta_{y,v}\right) \cdot \hat{v} + \zeta_{y,\sigma} \cdot \hat{\sigma} + \zeta_{y,m} \cdot \hat{m}. \tag{23}$$

Without a finance constraint ($\rho = 0$), a higher price shrinks demand by $\hat{C}_E = -\left(1 - \eta_s\right) \hat{v}$. 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, $\zeta \equiv C_E - X_E$. Defining $\hat{\zeta} \equiv vd\zeta/Y$ yields $\hat{\zeta} = \eta \hat{C}_E - \eta_s \hat{X}_E$, or

$$\hat{\zeta} = -\zeta_v \cdot \hat{v} - \zeta_\sigma \cdot \hat{\sigma} - \zeta_m \cdot \hat{m}, \tag{24}$$

where coefficients are, after substitution,

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

As long as ρ is not too large, $1 - \eta_s > \zeta_{y,v}$ must hold which implies $\zeta_v > 0$.[16] As long as the square bracket is positive, the other coefficients are positive as well. To see this, use

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

$\alpha = I_c x_c'/x_c$, $\eta_i = s_c I_c/(vp\bar{x})$ and $\rho = p(vx_c' - i) - c^m$ to obtain

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

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. Agents are compensated with sufficiently high income stakes to prevent both types of shirking. Welfare is equal to real income, $U = Y/v_D$, where v_D is the price index and changes by $\hat{U} = \hat{Y} - \eta\hat{v}$, giving

$$\hat{U} = [\rho\cdot\eta_i\eta_s(\varepsilon + \phi_v) - (\eta - \eta_s)]\cdot\hat{v} + \rho\cdot\eta_i\eta_s\phi_\sigma\cdot\hat{\sigma} + \rho\cdot\eta_i\eta_s\phi_m\cdot\hat{m}. \qquad (25)$$

In the first-best situation, $\hat{U} = -(\eta - \eta_s)\,\hat{v}$, i.e., a higher price reduces welfare of an import country with $\eta > \eta_s$ on account of a negative terms of trade effect. However, a higher price strengthens pledgable income, relaxes finance constraints and allows firms in the innovative sector to realize unexploited investment opportunities with strictly 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 in a small open economy, a small R&D subsidy boosts welfare since it relaxes the finance constraint. It thereby strengthens income by stimulating constrained expansion investment of innovative firms with an excess return. 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.

4.3 Policy Intervention

The following propositions summarize the consequences of seemingly different areas of policy intervention in a small open economy. The statements can be verified by the comparative static results in the preceding two subsections. We first turn to classical trade policy, consisting here of protection by raising non-tariff trade barriers. Protection in an import country raises the domestic price of the innovative good and leads to

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. If the trade deficit is small, national welfare rises in proportion to the excess return on investment of constrained firms.*

With a small trade deficit, i.e., $\eta \approx \eta_s$, the negative terms of trade effect of a higher price in an import country is also small, yielding a welfare gain from relaxing finance constraints. This result might justify a small level of protection to help 'infant industries' with many constrained firms that are unable to fully exploit their growth opportunities. The existence of finance constraints might be rooted in weak institutions like bad accounting rules, weak investor protection and other weaknesses in corporate governance. These shortcomings allow for managerial discretion and autonomy (high value of β_c), require large financial incentives to incentivize entrepreneurs and narrow down pledgable income and the financing capacity of firms. They could also be due to a rather immature financial sector with little effective monitoring and oversight of firms which again restricts access to external funding. While at least a small degree of protection might help to relax finance constraints and yield welfare gains, there might be other policies aiming more directly at the root of the problem. One possibility is an R&D subsidy which strengthens residual own assets and thereby helps innovative firms to gain access to external funding and to exploit their 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 finance 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 in R&D intensive goods. National welfare rises in proportion to the excess return on investment of constrained firms.*

Whereas trade protection raises the output price and thereby stimulates investment of both R&D intensive and standard firms in the innovative sector, the R&D subsidy is specifically targeted on finance constrained firms which are most in need of a subsidy in order to implement more projects with a strictly above normal rate of return. However, the aggregate implications are similar.

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 more passive 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. Obviously, unconstrained firms have no problem in raising external funds and therefore do not demand expensive monitoring capital. Financial development is inconsequential for these firms.

Proposition 5 ***(Financial development)*** *In a small open economy with a fixed output price, a higher monitoring productivity relaxes the finance constraint and stimulates* *investment, output and (expansion stage) profits of innovative firms while non-innovating firms are not affected. Financial development 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 in R&D intensive goods. National welfare rises in proportion to the excess return on investment of constrained firms.*

In the empirical literature, the volume of private credit in percent of GDP or the size of the venture capital market is often taken as a measure of a country's financial development. However, this measure is importantly demand-driven and may be unrelated to deep structural parameters determining the productivity of financial intermediation. R&D subsidies and trade protection of the innovative sector, for example, boost the demand for active finance both at the extensive (the share of innovating firms) and the intensive margin (investment scale per firm). The aggregate volume of active lending is $D_c^m s_c E$. In our model, a constrained firm raises informed capital in proportion to its investment level. Using the definition of γ in (7), the level of monitored credit per innovative firm is a fixed proportion of investment, $D_c^m = I_c \cdot c^m p_L/((p - p_L)\, R)$. Since both shocks boost innovation and subsequent capital investment of R&D intensive firms, the demand for active finance expands on extensive and intensive margins. Hence, a larger share of the country's fixed supply of assets is channeled through active financial intermediaries. This interpretation of 'financial development' is entirely demand-driven. The increased monitoring capacity as discussed above also boosts innovation and the subsequent growth of innovative firms. The volume of informed capital expands qualitatively in the same way, but this time it is driven by a real productivity gain in the financial sector.

We have discussed three rather different policy areas that could boost welfare in a small open economy 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, as measured in terms of monitoring intensity, what is the size of the R&D subsidy and of trade protection that would yield the same welfare gains?

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

First note that this statement excludes terms of trade effects by assuming balanced trade, i.e., $\eta = \eta_s$. The aim is to understand how protection affects financial frictions by raising the domestic price and not mix the welfare gains with terms of trade effects. However, in our model with homogeneous goods, protection is relevant only when the country is an importer. The proposition thus assumes an 'infinitesimally small' trade deficit in innovative goods so that consumer arbitrage leads to an increase in the domestic price as a result of protection. Given this qualification, and dividing the relationship by δI_c yields $(\varepsilon + \phi_v)\hat{v} = \phi_\sigma \hat{\sigma} = \phi_m \hat{m}$ and, thus, equally large effects of the three alternative policies on constrained firm investment, see (17), and on national welfare, see (24). Observe, however, that this policy equivalence does not carry over to innovation or aggregate supply. Looking at the change in the innovation threshold in (19) shows that the R&D subsidy boosts innovation more than financial sector development since the subsidy boosts innovation even in the absence of financial frictions while more intensive monitoring does not. A similar argument applies to a protection-induced price increase.

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. When the home economy is importing innovative goods, the price at home rises with import protection, $v = \tau v^*$, relative to the common world price v^* in all other countries, where $\tau = 1$ and $v = v^*$ at the outset.

Equilibrium in the world market requires $d\zeta + \sum_j d\zeta^j = 0$ where ζ^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 $\hat{\zeta}^j \equiv v^* d\zeta^j / Y^j$. The condition $\hat{\zeta}^* \equiv \omega\hat{\zeta} + \sum_j \omega^j \hat{\zeta}^j = 0$ for global market clearing 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 by $\hat{\zeta} = -\zeta_v (\hat{v}^* + \hat{\tau}) - \zeta_\sigma \hat{\sigma} - \zeta_m \hat{m}$, while excess demand in foreign countries changes by $\hat{\zeta}^j = -\zeta_v^j \cdot \hat{v}^*$ which yields

$$\hat{v}^* = -\omega \frac{\zeta_v}{\zeta_v^*} \cdot \hat{\tau} - \omega \frac{\zeta_\sigma}{\zeta_v^*} \cdot \hat{\sigma} - \omega \frac{\zeta_m}{\zeta_v^*} \cdot \hat{m}, \quad \zeta_v^* \equiv \omega \zeta_v + \textstyle\sum_j \omega^j \zeta_v^j, \tag{26}$$

where ζ_v^* is the GDP weighted average of individual country elasticities. The small open economy case results if the number of countries n gets large. This is most easily seen in the symmetric case where $\zeta_v^* = \omega n \zeta_v$, leading to $\hat{v} = -\left(\zeta_\sigma / \left(n\zeta_v\right)\right) \hat{\sigma}$. As $n \to \infty$ (implying $\omega \to 0$), an isolated shock in the domestic economy has only a negligible impact on the world market price. In a closed economy with $n = \omega = 1$, protection is irrelevant and the equilibrium price follows from $\hat{\zeta} = 0$ in (24).

5.1 Protection

If the home economy introduces non-tariff import barriers, 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 (26). Since $\omega\zeta_v/\zeta_v^* < 1$, protection raises the domestic price, but less than in a small open economy,

$$\hat{v} = (1 - \omega\zeta_v/\zeta_v^*) \cdot \hat{\tau} > 0. \tag{27}$$

Proposition 3 still applies, i.e., protection relaxes finance constraints and induces a supply expansion. If the trade deficit in innovative goods is small, the home country gains from a small degree of protection.

We can now state the spillovers on foreign economies. 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 yields the adjustment in a foreign country j.[17]

Proposition 7 ***(Protection spillovers)*** *(a) Domestic protection reduces the common world price v^* and thereby reduces foreign investments I_c^j and I_u^j, discourages foreign innovation by raising the cut-off values q^j, and reduces (magnifies) foreign trade surpluses (deficits). (b) Domestic protection tightens foreign finance constraints. Welfare of foreign export nations strongly falls since the negative terms of trade effect is reinforced by tightening finance constraints. Welfare of foreign import nations 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:

Proposition 8 ***(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 finance con-

[17] International welfare results from protection are similar to Egger and Keuschnigg (2010). That paper did not consider an explicit innovation decision and the coexistence of constrained and unconstrained firms in the innovative sector. Further, the analysis of trade implications of R&D subsidies and the discussion of financial sector development is new in the present paper.

straints 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 finance 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 (26) and the results of Section 3, we can state:

Proposition 9 ***(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 finance constraints and a deterioration of terms of trade while welfare changes in foreign import nations are ambiguous.*

It is unlikely that the negative feedback effect 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 is, the smaller is the impact on the world price v^*, and the smaller are the negative feedback effects. The feedback effect from 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 A, 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 standard, 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 $\hat{v}^* = -(\omega\zeta_m/\zeta_v^*)\,\hat{m}$, see (25). The lower price reduces investment and output of unconstrained, standard firms and retards the expansion of constrained innovative companies. The beneficial effects are thus scaled down.

Proposition 10 ***(Financial development in a large country)*** *The reduction in the world price dampens the supply-side expansion in the home country. 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 increase in innovation and welfare, and a smaller reduction of the trade deficit in innovative goods. (b) The declining 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 finance constraints and a deterioration of terms of trade while welfare changes in foreign import nations are ambiguous.*

In Appendix B, we give conditions such that the qualitative results of 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 standard ones. Standard 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 raise their debt capacity and allow them to profitably invest at a larger scale.

Using this framework, we investigate the role of three alternative policy instruments which affect financial frictions in distinct ways. These instruments are *trade 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 finance constraints. Welfare in foreign import countries changes ambiguously since terms of trade and financial frictions work in opposite ways.

Appendix

A. R&D Subsidy in a Closed Economy In autarky, where $\eta = \eta_s$, an R&D subsidy reduces the equilibrium output price by $\hat{v} = -(\zeta_\sigma/\zeta_v) \cdot \hat{\sigma}$. Plugging into (25) yields $\hat{U} = \rho\eta_i\eta\left[(\varepsilon + \phi_v)\hat{v} + \phi_\sigma\hat{\sigma}\right]$ or

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

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

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

where the last equality uses $q = kR/(\pi_c - \pi_u)$. The subsidy boosts welfare if innovation and firm composition are exogenous or inelastic ($\mu_\sigma \to 0$, $\mu_v \to 0$ implying $\Gamma \to 0$ and $\Omega_\sigma > 0$). The coefficient Ω_σ is also positive if $\frac{x_c - x_u}{\bar{x}} q^2 g(q)$ is small, i.e., if the subsidy moves only a few firms 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

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

where $\Omega_\sigma = \phi_\sigma \zeta_v - (\varepsilon + \phi_v)\,\zeta_\sigma$ is given above and is positive under the same conditions.

Finally, by (19), the extensive innovation margin in a closed economy changes by

$$\hat{q} = -\mu_v \cdot \hat{v} - \mu_\sigma \cdot \hat{\sigma} = -\frac{\Omega_q}{\zeta_v} \cdot \hat{\sigma}, \quad \Omega_q \equiv \mu_\sigma \zeta_v - \mu_v \zeta_\sigma > 0. \tag{A.3}$$

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

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

where the second line follows upon expanding ϕ_v in the first square bracket to $\phi_v + \varepsilon - \varepsilon$. Since $\frac{s_c x_c \alpha}{\bar{x}} - \rho\eta\eta_i > 0$ as noted subsequent to (24), an R&D subsidy clearly boosts innovation in a closed economy as well. In the first-best, ρ and all ϕ-coefficients are zero and $\mu_\sigma = 1$, giving $\Gamma = \varepsilon$ and $\Omega_q = (1-\eta_s)\,\eta + \alpha\varepsilon\eta_s$, which is clearly positive.

B. Financial Development in a Closed Economy: In autarky, the price reduction is $\hat{v} = -(\zeta_m/\zeta_v)\,\hat{m}$. Plugging into (25) yields $\hat{U} = \rho\eta_i\eta_s\left[(\varepsilon + \phi_v)\,\hat{v} + \phi_m \hat{m}\right]$ or

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

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

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

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,

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

The innovation threshold in (19) changes by $\hat{q} = -\mu_v \hat{v} - \mu_m \hat{m}$, which gives

$$\hat{q} = -\Omega/\zeta_v \cdot \hat{m}, \quad \Omega \equiv \mu_m \zeta_v - \mu_v \zeta_m. \tag{B.3}$$

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

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

where the term $\frac{s_c x_c}{\bar{x}} \alpha - \rho\eta\eta_i$ is positive by the result noted after (24). 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] Antras, Pol and Ricardo J. Caballero (2009), Trade and Capital Flows: A Financial Frictions Perspective, *Journal of Political Economy* 117, 701-744.

[3] Antras, 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 (2010), *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, Jiandong and Shang-Jin Wei (2008), *When is Quality of Financial System a Source of Comparative Advantage?*, NBER WP 13984.

[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.