Innovation, Trade, and Finance*

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Abstract

In this paper, heterogeneous firms invest in R&D and subsequent expansion investment. Venture capital specializes in R&D funding where financing problems are largest. Profitable firms with low potential get funded by venture capital while firms with larger debt capacity economize on costly monitoring and obtain bank financing. In the late-stage, cash-rich firms invest at an optimal scale while cash-poor firms are restricted. A country's financial and institutional development determines entry and expansion investment of firms and their comparative advantage in producing innovative goods. We illustrate how tariffs, R&D subsidies, institutional reform and venture capital improve access to capital, expand 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.

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1 Introduction

Despite their profitable investment opportunities, innovative firms are more frequently finance constrained than less innovative ones due to credit rationing (see Brown, Ongena, Popov, and Yeşin, 2011). R&D intensive sectors are thus financially dependent in the sense of Rajan and Zingales (1998). This paper sheds light on the mechanisms determining (endogenous) financing constraints on firms' R&D and subsequent expansion investments and on aggregate consequences for comparative advantage and trade. We assume that financing constraints in early-stage R&D root in a moral hazard problem in the relationship between entrepreneurs and outside investors as postulated in Holmstrom and Tirole (1997) and Tirole (2001, 2006). Depending on early-stage earnings as a result of R&D, firms end up either cash-rich or cash-poor when they move to the expansion stage. In this late-stage, cash-rich firms are able to invest at a first-best level while cash-poor firms are finance constrained. Depending on a country's institutional quality relating to accounting and reporting standards or investor protection, manager owners might divert funds towards their own use as in Ellingsen and Kristiansen (2011), Ellul et al. (2010, 2012) and Chetty and Saez (2010, 2005), for example, which limits firms' ability to repay and restricts access to external funds. For external funding to be incentive compatible, entrepreneurs must keep a minimum stake which limits the share of income pledgeable to outside investors. Hence, the level of pledgeable earnings 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. Entities we have in mind with the latter are venture capitalists (VCs), specialized investment banks or other intermediaries engaged in relationship banking. These informed financiers are specialized in financing the most difficult part of business investment, i.e., early-stage R&D by firms with little pledgeable earnings relative to own assets. Although their net value is strictly positive, these firms may not be able to obtain standard bank financing of early-stage R&D with high risk. However, VCs are able to monitor the firm and exercise oversight and control, thereby raising the firm's debt capacity and helping to raise a larger amount of external funds. This entails a *certification function* of VC which leads standard banks to extend additional credit to monitored (certified) entrepreneurs who would not get funded in the absence of monitoring. Hence, monitoring is beneficial by incentivizing entrepreneurs, raising firms' debt capacity, and improving access to external credit. VC financing is not suitable to all firms. Financially stronger firms with higher pledgeable earnings can economize on the extra costs of monitoring and obtain exclusive bank financing. The market for R&D financing is thus split between banks and VCs where VC serves the marginal and highly risky firms that could not get started otherwise while bank credit is available to those with lower risk. Since monitoring helps exploiting otherwise unused investment opportunities with positive net value, VC financing becomes valuable to innovative firms in spite of being more expensive than credit from standard bank financing.[1]

We model and interpret financial development as a productivity improvement in monitoring activities of VCs. As a consequence, financial development relaxes financing constraints, facilitates start-up R&D and entry into the innovative sector and thereby helps exploiting profitable investment opportunities at the extensive margin. In addition, we interpret institutional reform as an improvement of accounting and reporting standards, investor protection and other means to limit diversion of funds by mature firms. Institutional development similarly raises pledgeable earnings and debt capacity in the expansion stage and thereby allows cash-poor firms to finance more investment and earn larger profits. By raising the continuation value of start-ups, this feeds back positively on early-stage R&D funding. In this way, financial and institutional development becomes

[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 the riskiest among innovative firms. 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 innovative sectors. Kortum and Lerner (2000) found that venture capital is responsible for a disproportionately large share of U.S. industrial innovation. See Da Rin et al. (2011) for a survey.

a source of comparative advantage in financially dependent, innovative sectors. Such a framework allows for a deeper modeling of the sources of financial constraints and financial development relative to previous work.

We consider countries with two sectors: a standard sector where firms display low productivity and are not finance constrained so that the Modigliani-Miller irrelevance theorem applies; and an innovative sector where firms are potentially constrained in their access to external funds. Innovative production is driven by entrepreneurial firms which are heterogeneous in their early-stage survival probabilities. The riskiest among them can get started only with VC. The safer ones can economize on monitoring costs and exlusively finance R&D with bank credit. We study consequences of four alternative policy instruments which address financial frictions in distinct ways for (small or large) open economies.[2] The key results are the following. First, in raising the domestic price and earnings per firm, *import tariffs* boost earnings and the debt capacity of constrained firms. Import protection thereby relaxes financing constraints and allows more firms to enter the innovative sector and realize unexploited investment opportunities. For this reason, when market frictions prevent full financing of profitable investments, a small level of tariff protection can raise domestic welfare. The latter is an argument in favor of protection that relates to the case of infant industry protection in the absence of financial frictions (see Clemhout and Wan, 1970; and Mayer, 1984). A key argument was the existence of informational barriers which may prevent consumers to enter a contract with producers so that consumer experience was needed and, by protecting an infant industry, information costs were lowered.[3] In our model, gains from protection arise from informational barriers between producers and financial intermediaries (rather than consumers).[4]

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

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

[4] Notwithstanding, since protection entails a discriminatory treatment not only of domestic and foreign

Second, *R&D subsidies* boost innovation at the extensive entry margin and lead to welfare gains which arise not because of knowledge spillovers,[5] but because they augment own funds which, in turn, render innovating firms more successful in attracting external investors.[6] Altogether, this allows them to more fully exploit profitable investment opportunities. Akin to and beyond protection, an R&D subsidization policy boosts national welfare and shifts comparative advantage towards innovative industries.

Finally, we investigate the consequences of *financial and institutional development.* Since monitoring is useful only for financially constrained, innovative firms, improved monitoring productivity in VC financing relaxes the financing constraint on early-stage R&D spending, boosts entry by raising the debt capacity of innovative start-ups, and enhances national welfare. A better institutional environment limits diversion of funds and strengthens the financing capacity of cash-poor firms in the expansion stage. Allowing them to better exploit unused investment opportunities strengthens profits which positively feeds back to start-ups by raising their continuation value. The quality of the financial sector as well as the institutional environment becomes a source of comparative advantage in the R&D intensive and financially dependent sector.

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

firms but also of innovative and non-innovative sector firms, other instruments as discussed in the paper will have less distorting effects and are preferable to protection of the innovative sector.

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

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

terms-of-trade gains which tend to offset the negative effects on financial frictions.

The novel contributions of the present paper compared to earlier work on the real effects of financial constraints in open economies are as follows. First, financial frictions affect early-stage R&D and late-stage expansion investment in different ways and lead to emergence of different financial intermediaries. In particular, we assign a unique role to VC in financing the marginal and riskiest part of early-stage R&D while exclusive bank financing is available for relatively safe R&D and subsequent expansion investment of mature firms. Financial constraints are driven by deep characteristics of the financial industry, leading to endogenous market segmentation between standard banks and informed VC. The tightness of financing constraints and market segmentation depend inter alia on structural parameters relating to costs and effectiveness of monitoring. While VC is more costly than standard bank credit, it brings about a certification effect for R&D intensive firms which helps them to raise additional standard credit and to better exploit highly profitable investments. Monitoring and control helps to finance early-stage R&D, stimulates entry into the sector and leads to a larger number of innovative firms. A better monitoring technology reduces the costs of certification and endogenously improves access to external capital. Second, we analyze and compare four different policies – tariff protection of the innovative sector, R&D subsidies, and financial as well as institutional development – with regard to their impact on financial constraints, national equilibrium, and the pattern of a country's trade. 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 in Section 2 with 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. Section 6 discusses the implications for financial structure and alternative roles of VC financing. The concluding section summarizes the key insights.

2 Real Effects of Finance: Empirical Evidence

The main building blocks of our model – both with regard to the sources and the consequences of financial constraints – are well backed by empirical evidence. In what follows, we summarize findings of empirical work on the roots as well as the consequences of financial constraints. In a seminal paper, Rajan and Zingales (1998) show that, at the macro level, poorly developed financial markets are one important reason for financing constraints which impair the growth of companies dependent on external finance. Similarly, access to external finance is more constrained in countries with poorly developed property rights (Beck, Demirgüç-Kunt, and Maksimovic, 2008). Moreover, work by Hoshi, Kashyap, and Scharfstein (1991), Schaller (1993), and Chirinko and Schaller (1995) points to information asymmetries between financial intermediaries and firms as a source of financing constraints: when firms have close ties to banks, the informational asymmetry is reduced, and they are more likely to obtain the required funding. There is evidence that such financing constraints are particularly severe for small firms (see Fisman and Love, 2003; Beck, Demirgüç-Kunt, and Maksimovic, 2005, 2008; Aghion, Fally, and Scarpetta, 2007). It appears that firm size matters for external credit even in developed countries with relatively mature 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). 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 and high risk – are ceteris paribus more constrained (Himmelberg and Petersen, 1994; Guiso, 1998; Ughetto, 2008, 2009; Bloom, Griffith and Van Reenen, 2002; Hall, 2002; Brown and Petersen, 2009; Hall and Lerner, 2009).

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

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

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 traditional Ricardian sector produces the *numéraire* good with a linear technology that transforms one unit of capital into one unit of output at no risk. Hence, the return on safe investment is zero. The innovative sector consists of heterogeneous firms, run by entrepreneurs who make risky innovation and investment choices. The country hosts a unitary mass of risk-neutral individuals endowed with assets A_0 per capita, entrepreneurial talent and heterogeneous project ideas. A fraction E with more promising projects enters the innovative sector, starts a firm and invests in risky R&D which may result in high or low productivity. If firms survive the initial R&D phase, they choose expansion investment and produce final output. The remaining part $1 - E$ abstains from entrepreneurship and invests wealth in the capital market. In addition to entrepreneurs, a mass Z of investors is endowed with capital a per capita, but those investors have no managerial talent.[8] All capital that is not invested in the innovative sector is used to produce traditional sector output.

Innovative firms must partly finance R&D and expansion investment by raising external funds. The model embeds two types of capital market frictions: moral hazard limits risky early-stage financing, while investment of mature firms is limited by the potential diversion of funds as in Pagano et al. (2011). In the late stage, firms differ by the amount of own funds inherited from early-stage earnings. Large, cash-rich firms are unconstrained, investing the first-best amount of capital. Cash-poor firms are constrained by the di-

2009), and alters the decision to deploy technology through foreign direct investment as opposed to arm's length technology transfers. The latter lies beyond the scope of this paper.

[8]The existence of investors serves two purposes in the model. First, their endowment guarantees positive output in the Ricardian sector. Second, they serve as a source of truly lump-sum tax revenue that does not induce additional distortions on financing decisions or the occupational choice of entrepreneurs.

version of funds (see also Chetty and Saez, 2010). This set-up allows us to distinguish investor protection (antidirector rights, etc.) in mature firms from problems with access to capital by small innovative firms in the early stage. The weakest ones must seek venture capital (VC) to get funded. Venture capitalists (VCs) have monitoring skills and are able to lend when exclusive bank financing is no longer possible. Given monitoring and the associated certification by VCs, banks are willing to lend the remaining investment funds (in addition to their financing of unconstrained firms). A viable VC sector thus relaxes credit constraints on innovative firms.

Early-stage firms are created by potential entrepreneurs who are endowed each with a project of variable quality $q \in [0,1]$, distributed with density $f(q)$. A firm's type is the probability q that fixed R&D spending k results in high output $\theta_h > \theta_\ell$. With probability $1-q$, output turns out low. A high q-type is more innovative in that R&D is more likely to result in high output. All agents have symmetric information with regard to a firm's type. A firm's life-cycle involves the following sequence of events: (i) part E of the potential entrepreneurs enter the innovative sector; (ii) firms invest in R&D and choose the financing mode, either bank financing (index b), or VC financing with active monitoring (index m); (iii) entrepreneurs choose high or low effort and VCs choose whether to engage in active monitoring or not; (iv) production risk is realized: start-ups survive with probability p, or fail and are left with nothing; if successful, output is high with probability q or low with probability $1-q$; (v) given variable earnings from early-stage output, firms continue with mature stage investment and production.

When surviving the start-up period, a firm may end up in four different states, depending on the financing mode, index $f \in \{m, b\}$, and the R&D result, index $j \in \{h, \ell\}$. Given an output price v, earnings $v\theta_j$ are either high or low. A bank-financed (unmonitored) firm repays R_b. A VC-backed firm must repay R_m to VCs and R_{bm} to banks. In turn, own funds A_{jf} available for self-financing of expansion investment amount to

$$A_{jb} = v\theta_j - R_b, \quad A_{jm} = v\theta_j - R_{bm} - R_m. \tag{1}$$

Once the outcome of the start-up period is known, a firm generates a surplus π_{hf} in the expansion phase. Prior to knowing the R&D outcome, the expected continuation value of a type-q firm is $pW_f(q)$, where

$$W_f(q) = q \cdot (v\theta_h + \pi_{hf}) + (1-q) \cdot (v\theta_\ell + \pi_{\ell f}) = v\theta_\ell + \pi_{\ell f} + q \cdot \nabla_f, \tag{2}$$

and $\nabla_f \equiv v(\theta_h - \theta_\ell) + \pi_{hf} - \pi_{\ell f}$.

Innovators start with little own resources A_0 and need external funds to finance R&D. If a firm opts for bank financing only, it raises a credit $D_b \equiv (1-\sigma)k - A_0$ and expects a surplus $\Pi_b(q) = p[W_b(q) - R_b] - A_0$. The safe deposit rate is normalized to zero. Profits of banks are $pR_b - D_b \geq 0$. Perfect competition reduces them to zero. Entrepreneurs thus appropriate the entire surplus of the project,

$$\Pi_b(q) = pW_b - (1-\sigma)k. \tag{3}$$

If a firm opts for VC financing, it raises a part D_m from VCs while the remaining part $D_{bm} \equiv (1-\sigma)k - A_0 - D_{mm}$ is provided by standard banks. A firm's early-stage surplus is $\Pi_m(q) = p[W_m(q) - R_m - R_{bm}] - A_0$. In contrast to regular banks, VCs engage in monitoring and oversight, incurring extra costs k_m. VC profits are $pR_m - D_{mm} - k_m \geq 0$ and banks earn $pR_{bm} - D_{bm} \geq 0$. With perfect competition among intermediaries, firms will never leave a positive profit to banks and VCs. Provided that she is able to get financing, an entrepreneur thus obtains the entire surplus equal to

$$\Pi_m(q) = pW_m - (1-\sigma)k - k_m. \tag{4}$$

For later use, we record total repayment $p(R_m + R_{bm}) = D_m \equiv (1-\sigma)k - A_0 + k_m$.

A mature firm invests a variable level of equipment I_{jf} to produce with a piecewise linear technology. Capital $I_{jf} \leq \bar{I}$ yields output GI_{jf} of the innovative good which sells at a price v per unit. Investment in excess of $\bar{I}$ is unproductive. Gross earnings are

$$w_{jf} = vGI_{jf} \text{ for } I_{jf} < \bar{I}, \quad w_{jf} = vG\bar{I} \text{ for } I_{jf} \geq \bar{I}. \tag{5}$$

Optimal investment never exceeds $\bar{I}$. A higher value would be costly but yield no return.

There is no production risk in the late stage. Empirically, failure rates are high early on and decline with firm age. External funding $vI_{jf} - A_{jf}$ of late-stage investment is limited by the potential diversion of funds, instead of moral hazard.[9] Given a repayment R_{jf}, late-stage surplus becomes $\pi_{jf} = w_{jf} - R_{jf} - A_{jf}$. Competition among banks reduces repayment to $R_{jf} = vI_{jf} - A_{jf}$, which leaves the entrepreneur with

$$\pi_{jf} = w_{jf} - vI_{jf}. \tag{6}$$

Using $G \equiv 1 + g$, the net value is $\pi_{jf} = vgI_{jf}$ with $I_{jf} \leq \bar{I}$. The model is solved backwards by first determining late-stage investment. The values in the mature stage define continuation values of early-stage R&D in (2) and total expected values of VC-backed or bank-financed entrants as in (3)-(4).

3.2 Late Stage Investment

When investment is sunk, earnings and repayment are fixed. We assume that insiders may divert a part ϕ' of earnings up to a maximum level ϕ which reflects a country's institutional quality reflected in its investor protection, antidirector rights and transparency rules. Owners may divert an amount $\phi' w_{jf}$ of earnings, leaving only the remaining part to repay external funds. The sum of diverted and residual income is $\phi' w_{jf} + [(1 - \phi') w_{jf} - R_{jf}]$. If previously agreed repayment is less than maximum pledgeable earnings, $(1 - \phi) w_{jf} > R_{jf}$, diverting resources does not yield any benefit. If diversion creates an infinitesimally small cost, it is optimally set to zero and debt is fully repaid. However, if a firm is loaded with too much debt such that $(1 - \phi) w_{jf} < R_{jf}$, it is optimal to divert the maximum amount, leaving the insider (i.e., the manager-owner) with ϕw_{jf} only. Since residual income cannot be negative, the firm defaults and repays only $(1 - \phi) w_{jf}$, which is less than the promised repayment.

To prevent diversion, banks must limit credit so that repayment does not exceed pledgeable earnings, $(1 - \phi) w_{jf} > R_{jf} \geq vI_{jf} - A_{jf}$. The firm offers the minimum

[9] For simplicity, we assume that late-stage investment I_{jf} is in terms of innovative goods, creating a cost vI_{jf}, while early-stage investment k requires standard goods.

repayment that assures the banks' participation, $R_{jf} = vI_{jf} - A_{jf}$. The resulting surplus $\pi_{jf} = vgI_{jf}$ rises linearly with investment as the excess return g is non-diminishing (up to the maximum scale). Hence, the firm scales up investment and asks for more external funds until the no-diversion constraint binds, $(1-\phi) vGI_{jf} \geq vI_{jf} - A_{jf}$. Figure 1 illustrates this relationship. When pledgeable earnings grow slower than repayment, $(1-\phi) vG < v$, the constraint becomes binding at a finite investment level, given by

$$I_{jf} = \min \left\{ A_{jf}/ (\delta v), \bar{I} \right\}, \quad \delta \equiv 1 - (1-\phi) G, \quad 0 < \delta < 1. \tag{7}$$

Since earnings are capped, the firm invests only up to $\bar{I}$.

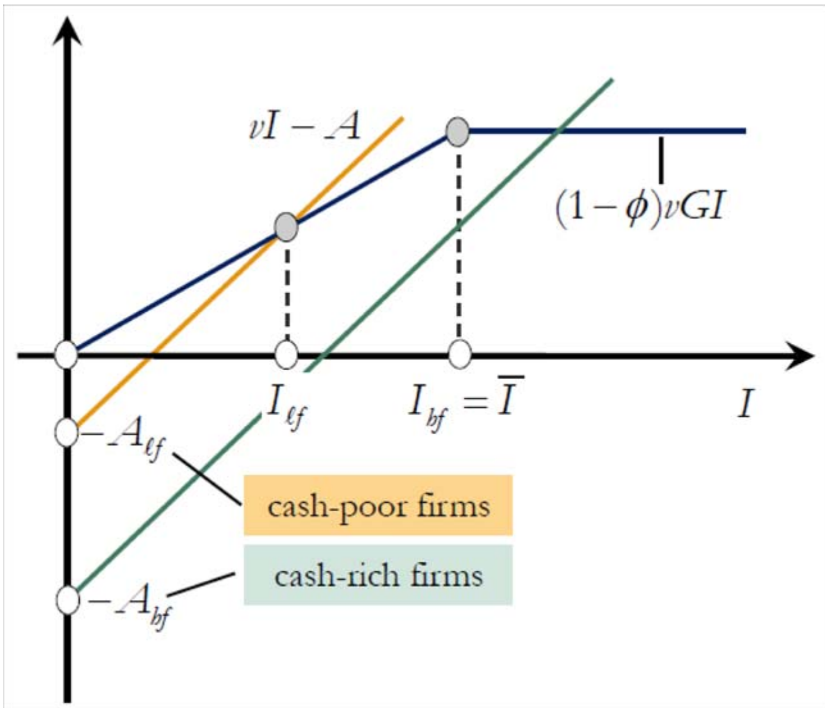

Fig. 1: Expansion Investment

As a stylized fact, cash-rich firms are unconstrained and cash-poor ones are financially constrained which requires $A_{hm} > v\delta\bar{I} > A_{\ell b}$, see (7), which leads to

Assumption 1 *R&D outputs θ_j satisfy $\theta_h - k_m/(vp) > [(1-\sigma) k - A_0] / (vp) + \delta\bar{I} > \theta_\ell$.*

Internal funds differ by the financing mode and early-stage earnings. Trivially, we have $A_{hf} > A_{\ell f}$. Zero profits in financial intermediation imply $p(R_m + R_{bm}) = pR_b + k_m$

which results in $A_{hm} - A_{\ell b} = v(\theta_h - \theta_\ell) - k_m/p > 0$ by Assumption 1. Since VC financing is more expensive, we also have $A_{jb} > A_{jm}$. These inequalities imply the ordering $A_{hb} > A_{hm} > A_{\ell b} > A_{\ell m}$. By Assumption 1, and in line with empirical evidence, large, cash-rich firms invest up to the maximum scale while small, cash-poor firms are financially constrained and invest less,

$$I_{\ell f} = A_{\ell f}/(\delta v) < \bar{I}, \quad I_{hf} = \bar{I}. \tag{8}$$

The surplus then amounts to $\pi_{\ell f} = vgI_{\ell f}$ and $\pi_{hf} = vg\bar{I}$. Cash-poor firms are left with unexploited investment opportunities. They could further raise their surplus by expanding investment if financing were available.

3.3 Innovation, Access to Capital, and Entry

Access to credit is mainly a problem of young, innovative start-ups with little own funds. When an entrepreneur considers entry, she must seek for appropriate external funds to finance the initial R&D investment. She first compares the value of the new firm under bank and VC financing and then chooses the option which yields the larger value.

Bank Financing: With bank financing, the continuation value of a new firm of type q is $W_b(q)$. To finance R&D, it needs external funds and must promise a large-enough repayment. It will be denied credit if banks cannot safely expect full repayment due to moral hazard. After R&D is sunk and repayment is fixed, the entrepreneur expects a net value in the success state equal to $W_b - R_b$. If this is too low, she might shirk and enjoy private benefits $\tilde{B}$. Shirking reduces the success probability to $p_L < p$ and thereby diminishes expected wealth. If p_L is small, a project will have negative net value so that either the bank cannot break even and denies credit or the entrepreneur would not want to start the firm. The contract must thus guarantee high effort and satisfy the incentive constraint $p(W_b - R_b) \geq p_L(W_b - R_b) + \tilde{B}$.[10] Using $B \equiv p\tilde{B}/(p - p_L)$,

$$p[W_b(q) - R_b] \geq B \quad \Leftrightarrow \quad \Pi_b(q) = pW_b(q) - (1-\sigma)k \geq B - A_0 > 0. \tag{9}$$

Residual wealth after repaying credit must be large enough to assure high effort. If the continuation value is too small, effort slackens. There is a lowest type q_b, given by $\Pi_b(q_b) = pW_b(q_b) - (1-\sigma)k = B - A_0 > 0$, for whom the constraint binds. Firms with still lower quality are denied credit even though they generate a positive net value. To assure the existence of credit rationing, we introduce

Assumption 2 *Private benefits are large, $B \equiv p\tilde{B}/(p - p_L) > A_0$.*

VC Financing: Although exclusive bank financing is not possible for types $q < q_b$, these firms could still obtain VC which can raise a firm's pledgeable income by exercising monitoring and control. We assume that VC oversight reduces private benefits to $\tilde{b} < \tilde{B}$ and thereby incentives to shirk. On the other hand, VCs cannot commit to high monitoring effort either. Once the contract is signed, they might want to shirk and consume private benefits γ. Without monitoring, the entrepreneur could consume large private benefits which violates the financing condition for types $q < q_b$. With double moral hazard, the contract must simultaneously satisfy two incentive constraints,

$$(p - p_L)(W_m - R_{bm} - R_m) \geq \tilde{b}, \quad (p - p_L)R_m \geq \gamma. \tag{10}$$

To maximize residual wealth, the optimal contract (see Appendix A for details) offers the smallest repayments R_{bm} and R_m that make participation constraints of banks and VCs binding and still satisfy the incentive constraints in (10). Since a larger credit and repayment reduces pledgeable earnings, a firm economizes on VC funding and thus offers a minimum repayment $R_m = \gamma/(p - p_L)$ that just assures incentives for active monitoring. Knowing this, it extracts the VC rent by asking for funds of $D_m = pR_m - k_m$, raises the remaining credit from banks, and promises a repayment of $pR_{bm} = (1-\sigma)k - A_0 - D_m$.

[10] See Appendix A for a more detailed derivation of optimal contracts under VC and bank financing.

With joint VC and bank financing, total repayment $p(R_m + R_{bm}) = (1-\sigma)k - A_0 + k_m$ must satisfy the entrepreneur's incentive constraint which reduces to

$$\Pi_m(q) = pW_m(q) - (1-\sigma)k - k_m \geq b - A_0. \tag{11}$$

There is a least-profitable type q_m such that the financing constraint becomes binding, $\Pi_m(q_m) = b - A_0 > 0$. If this constraint is fulfilled, a firm of type $q > q_m$ can get financed with joint VC and bank financing.

Comparing (9) and (11) shows that $q_m < q_b$ holds if the condition for bank financing is violated for low types, $q \in [q_m, q_b]$, while VC financing is still possible. Figure 2 illustrates this relationship and motivates

Assumption 3 *Monitoring is effective,* $pW_b(q) - B < (1-\sigma)k - A_0 < pW_m(q) - k_m - b$.

VC monitoring thus reduces private benefits to a sufficient degree to compensate for the additional costs, $B - b > k_m + p(W_b - W_m)$. The last term results from the fact that VC is more expensive and drains internal funds relative to exclusive bank financing, $A_{jm} < A_{jb}$. Hence, investment of cash-poor firms is somewhat smaller under VC financing, implying $\pi_{\ell m} < \pi_{\ell b}$, while cash-rich firms always invest at the unconstrained level $\bar{I}$ and get the same surplus in both financing modes, $\pi_{hm} = \pi_{hb}$. Hence, $W_b(q) > W_m(q)$, i.e., VC financing not only adds extra monitoring costs but also slightly reduces a firm's continuation value. Hence, the benefit of improved access to external funds must be sufficiently large for VC financing to become viable.

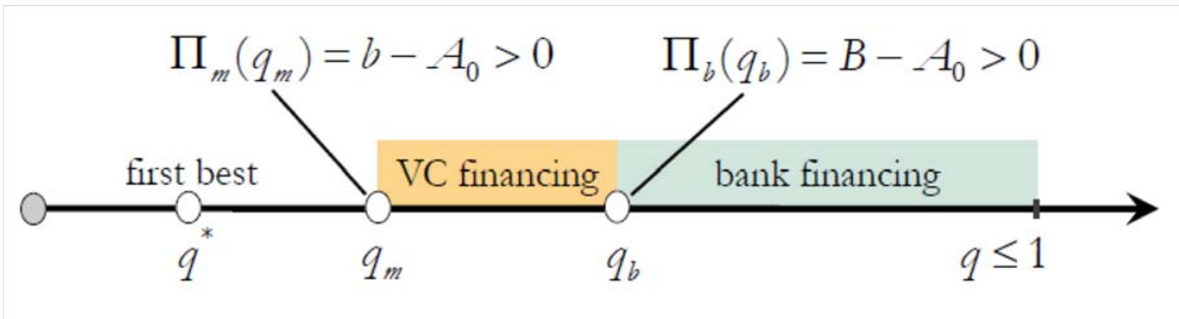

Fig. 2: VC and Bank Financing

Under either financing mode, the surplus is larger for more innovative firms as expected value $W_f(q)$ rises with q. Since monitoring costs make VC financing more expensive, firms do not ask for VC financing if they do not need it. Stronger firms $q > q_b$ have high pledgeable wealth and are exclusively financing with bank credit since their continuation value is higher under this option, $W_b(q) > W_m(q) > 0$. Weaker firms of types $q_m < q < q_b$ are denied bank credit, but can still obtain VC financing jointly with residual bank credit. In this sense, VCs have a certification role and help weak firms to get access to capital. The continuation value of VC-financed firms is $W_m(q)$. There is a pivotal, VC-backed firm of type q_m which is indifferent between entry or not. Types $q < q_m$ do not get funded under either option and invest their wealth in the Ricardian sector instead.

First Best: In the first-best case where external bank financing is not restricted by moral hazard, VC has no value and is not used. Mature investment is at $\bar{I}$ in all cases, giving $\bar{\pi} = vg\bar{I}$ and $W = qv\theta_h + (1-q)v\theta_l + \bar{\pi}$. Entry would occur until $\Pi(q^*) = pW(q^*) - k = 0$. The pivotal values satisfy $0 < q^* < q_m < q_b < 1$. Moral hazard thus introduces credit rationing of projects $q \in [q^*, q_m]$ with a positive net value. The role of VC is to relax the financing constraint with respect to innovation financing and allow additional start-ups with positive net value to get financed.

3.4 General Equilibrium

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

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

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

On the supply side, we must translate the life-cycle into a cross-section of firms. Since an entrant's surplus rises with q, only the more innovative types enter. Marginal entrants are VC-financed, firms with higher potential have access to cheaper bank credit. The two groups add up to a total number of entrants $E = E_m + E_b$. Each group is further decomposed into more and less profitable firms, depending on prior innovation outcome. Shares add up to unity, $s_{hf} + s_{\ell f} = 1$:

$$\begin{aligned} E_m &= \int_{q_m}^{q_b} dF(q), \quad s_{hm} = \int_{q_m}^{q_b} q\,dF(q)/E_m, \quad s_{\ell m} = \int_{q_m}^{q_b} (1-q)\,dF(q)/E_m, \\ E_b &= \int_{q_b}^{1} dF(q), \quad s_{hb} = \int_{q_b}^{1} q\,dF(q)/E_b, \quad s_{\ell b} = \int_{q_b}^{1} (1-q)\,dF(q)/E_b. \end{aligned} \tag{13}$$

For concise notation, we define aggregate variables such as

$$I_E \equiv \sum_f E_f \sum_j s_{jf} I_{jf} = I_M E_m + I_B E_b, \tag{14}$$

where $I_M \equiv \sum_j s_{jm} I_{jm}$ ($I_B \equiv \sum_j s_{jb} I_{jb}$) is average expansion investment of a VC-financed (bank-financed) firm. Similarly, $\theta_E = \theta_M E_m + \theta_B E_b$ with $\theta_B = \sum_j s_{jb}\theta_j$. For later use, we also note, upon substituting A_{jf} together with repayments in (3)-(4), $A_E \equiv \sum_f E_f \sum_j s_{jf} A_{jf}$ as well as $pA_E = pv\theta_E - D_E$ and $D_E \equiv D_b E_b + (D_m + D_{bm}) E_m$.

The rent of a marginal entrant is still positive, indicating credit rationing. Better innovators earn a larger rent, adding up to $\Pi_E = \int_{q_m}^{q_b} \Pi_m(q)\,dF(q) + \int_{q_b}^{1} \Pi_b(q)\,dF(q)$. Using (2-4), aggregate rents amount to $\Pi_E = E_b \Pi_B + E_m \Pi_M$ where average rents of VC- and bank-financed firms are

$$\Pi_M = p(v\theta_M + \pi_M) - (1-\sigma)k - k_m, \quad \Pi_B = p(v\theta_B + \pi_B) - (1-\sigma)k. \tag{15}$$

Entrepreneurs are endowed with A_0 per capita. Investors pay a per capita tax t_Z, yielding an individual end-of-period income of $y_I = a - t_Z$ and total disposable income of investors of $A_Z = (a - t_Z) Z$. Endowments (in terms of the numéraire good) are spent on R&D investments and standard sector investment I_N. The resource constraint is $aZ + A_0 = kE + k_m E_m + I_N$ and equates lending and borrowing,

$$aZ + A_0 (1 - E) = (k - A_0) E + k_m E_m + I_N. \tag{16}$$

Entry is fixed by fundamentals. Capital market clearing residually determines standard sector investment and holds identically.

Of all entrepreneurial agents, $1 - E$ go to the traditional sector and have $y_N = A_0$ at the end, and pE survive the early stage, with a share s_{jf} ending in state j with income $y_{jf} = \pi_{jf} + A_{jf}$. Using average values, end-of-period wealth is endowments plus rents,[11]

$$Y = A_Z + (1 - E) A_0 + \textstyle\sum_f E_f \sum_j s_{jf} p (\pi_{jf} + A_{jf}) = A_Z + A_0 + \Pi_E. \tag{17}$$

To close the model, we state the fiscal constraint. The government collects a per-capita tax t_Z from investors and tariffs to finance R&D subsidies. The country may impose an ad-valorem tariff τ on imports of innovative goods. Buyer arbitrage links domestic and foreign prices by $v = (1 + \tau) v^*$. Given aggregate supply and demand of innovative goods, X_E and C_E, and noting tariff revenue T, the fiscal budget constraint is

$$t_Z Z + T = \sigma k E, \quad T \equiv \tau v^* (C_E - X_E). \tag{18}$$

Aggregate consumer spending amounts to $C_N + vC_E = Y$. Let $X_E \equiv p (\theta_E + gI_E)$ be output of the innovative industry (net of investment spending in the expansion stage) and $X_N \equiv I_N$ standard sector output equal to residual investment. Using (15) together with $\pi_M = vgI_M$ and $\pi_B = vgI_B$, the government budget (18) and the capital market condition in (16), and noting the definition of X_E, aggregate income or end-of-period wealth in (17) is $Y = vX_E + I_N + T$. Substituting into the aggregate consumer budget and noting price arbitrage on the international goods market, $v = (1 + \tau) v^*$, yields the trade balance condition

$$(C_N - X_N) + v^* (C_E - X_E) = 0. \tag{19}$$

[11] Note $\sum_f E_f \sum_j s_{jf} p (\pi_{jf} + A_{jf}) = E_b p \pi_B + E_m p \pi_M + pA_E = \Pi_E - A_0 E$, where the last equality uses $pA_E = p (E_b v \theta_B + E_m v \theta_M) - D_E$ as well as $D_E = D_b E_b + (D_m + D_{bm}) E_m$ which is equal to $D_E = (1 - \sigma) kE_b + ((1 - \sigma) k + k_m) E_m - A_0 E$. Noting the definitions in (15) yields the result.

This establishes Walras' Law since capital market clearing holds identically by residually determining I_N. In a closed economy, the output price v adjusts to determine general equilibrium. Equating $C_E = X_E$ implies $C_N = X_N$ by the trade balance condition.

In a small economy, the world price v^* is given. The equilibrium solution is recursive and involves the following steps: (i) zero profit conditions yield repayments to banks and VCs; (ii) repayments imply retained earnings A_{jf} as well as late-stage investment and surplus, I_{jf} and π_{jf}; continuation values are $W_f(q)$ and net values $\Pi_f(q)$; (iii) financing constraints (9) and (11) determine the pivotal type q_b separating VC- and bank-financed firms, and the marginal entrant q_m which is VC-financed; now the number of start-ups $E = E_b + E_m$ and total rent Π_E of innovators are known; (iv) (16) yields residual investment I_N in the traditional sector, (17) gives income Y, and (12) determines consumer demands $C_N = (1-\eta) Y$ and $C_E = \eta Y/v$; as a last step, one finds industry outputs X_E and X_N and the trade balance.

4 Small Open Economy

We study how three distinct areas of policy intervention, import protection, R&D subsidies and financial development, can shape the trade structure and affect welfare in a small open economy. We discuss the distinct effects of more active venture capital financing of innovative start-ups and of investor protection relating to external financing of more mature firms. Buyer arbitrage links domestic and foreign prices by $v = (1+\tau) v^*$ where τ is an import tariff. When analyzing tariffs, we assume the country to be an importer of innovative goods.[12] A small open economy cannot affect the common world price v^* of the innovative good in all other countries. Hence, import protection raises the domestic price by $\hat{v} = \hat{\tau} \equiv d\tau/(1+\tau)$. To avoid complicated tax base effects, we assume the initial equilibrium to be untaxed, i.e., $\sigma = t_Z = \tau = 0$.

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

4.1 Firm Level Adjustment

Internal funds depend on early-stage earnings $v\theta_j$ and the firm's financing choice. Noting definitions in (3)-(4), $pA_{jf} = vp\theta_j - D_f$. An R&D subsidy reduces the need for external innovation financing, resulting in smaller repayments and higher internal funds for late-stage investment, $pdA_{jf} = p\theta_j dv + kd\sigma$. Cash-rich firms ($A_{hf}$ high) invest at the first best level and do not expand further. In contrast, cash-poor firms are constrained, meaning that investment becomes sensitive to internal funds. By (8), and using $\hat{\sigma} \equiv d\sigma$ and $\hat{\phi} \equiv d\phi/(1-\phi)$, we have

$$\hat{I}_{\ell f} = \varepsilon_{vf} \cdot \hat{v} - \varepsilon_{\phi} \cdot \hat{\phi} + \varepsilon_{\sigma f} \cdot \hat{\sigma}, \quad \hat{I}_{hf} = 0. \tag{20}$$

Coefficients $\varepsilon_{vf} \equiv \frac{D_f}{pA_{\ell f}}$, $\varepsilon_{\phi} = \frac{(1-\phi)G}{\delta}$ and $\varepsilon_{\sigma f} \equiv \frac{k}{pA_{\ell f}}$ are always defined positive. Higher prices and better investor protection (lower ϕ) boost investment by raising pledgeable earnings and thereby improving access to external funds. Higher R&D subsidies also stimulate late-stage investment by strengthening internal funds which get leveraged with additional external credit. 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.

A higher price directly boosts profit and surplus of mature firms. In addition, cash-poor firms are left with unexploited investment opportunities and can still raise their surplus by investing at a larger scale, $d\pi_{\ell f} = \pi_{\ell f} \cdot (\hat{v} + \hat{I}_{\ell f})$. No such gain is present with cash-rich, unconstrained firms,

$$d\pi_{hf} = \pi_{hf} \cdot \hat{v}, \quad d\pi_{\ell f} = \pi_{\ell f} \left[(1 + \varepsilon_{vf}) \cdot \hat{v} - \varepsilon_{\phi} \cdot \hat{\phi} + \varepsilon_{\sigma f} \cdot \hat{\sigma} \right]. \tag{21}$$

Since $\bar{I} > I_{\ell f}$, cash-rich firms generate a larger surplus, $\pi_{hf} - \pi_{\ell f} = vg\left(\bar{I} - I_{\ell f}\right) > 0$.

In the start-up phase, firms differ in their innovation potential, indexed by type q. A firm's continuation value from successful R&D investment in (2) depends on the financing mode and rises with the firm's potential q and expected future profits,

$$dW_f = \nabla_f \cdot dq + q \cdot (v\theta_h \hat{v} + d\pi_{hf}) + (1-q) \cdot (v\theta_\ell \hat{v} + d\pi_{\ell f}). \tag{22}$$

High-potential firms have sufficient pleadgeable earnings and choose bank financing of R&D investment, while some weaker firms can get started only if they are able to engage a VC. The constraint in (9) pins down the weakest, bank-financed type q_b. At the lower margin, the constraint (11) determines the marginal VC-backed firm, q_m. Taking the differential of these two conditions pins down how policy shocks affect entry. Evaluating (21)-(22) at the threshold levels yields

$$\begin{aligned} \hat{q}_b &= -\mu_{vb} \cdot \hat{v} + \mu_{\phi b} \cdot \hat{\phi} - \mu_{\sigma b} \cdot \hat{\sigma}, \\ \hat{q}_m &= -\mu_{vm} \cdot \hat{v} + \mu_{\phi m} \cdot \hat{\phi} - \mu_{\sigma m} \cdot \hat{\sigma} + \mu_{bm} \cdot \hat{b}. \end{aligned} \tag{23}$$

Again, coefficients $\mu_{vf} \equiv \frac{W_f(q_f)+(1-q_f)\pi_{\ell f}\varepsilon_{vf}}{q_f \nabla_f}$, $\mu_{\sigma f} \equiv \frac{(1-q_f)\pi_{\ell f}\varepsilon_{\sigma f}+k/p}{q_f \nabla_f}$, $\mu_{\phi f} \equiv \frac{(1-q_f)\pi_{\ell f}\varepsilon_{\phi}}{q_f \nabla_f}$ and $\mu_{bm} \equiv \frac{b/p}{q_m \nabla_m}$ are all defined positive.

A higher price boosts continuation values and strengthens pledgeable earnings in early-stage financing. More firms are able to avoid costly VC financing of R&D and instead rely exclusively on bank financing, $\hat{q}_b = -\mu_{vb} \cdot \hat{v}$. By the same reasoning, VCs are able to finance additional entrants if pledgeable earnings rise, $\hat{q}_m = -\mu_{vm} \cdot \hat{v}$. Better investor protection (lower ϕ) boosts late-stage investment and profits of constrained firms. Since both VC- and bank-financed firms may end up being cash-poor when initial earnings turn out low, better investor protection benefits all early-stage firms whether VC financed or not. As a result, both threshold values fall so that some firms switch from VC to bank financing, and VCs are able to finance more entrants. The same holds for R&D subsidies which make firms less dependent on external credit. Finally, a more active VC industry monitors more aggressively and is able to impose tighter control. More intensive VC oversight narrows down private benefits b (for any given monitoring effort and fixed cost, k_m and γ), and thereby boosts pledgeable earnings. As debt capacity rises, more firms with low innovation potential but strictly positive net value are able to finance entry, i.e., $\hat{q}_m = \mu_{bm} \cdot \hat{b}$ falls with lower b. Obviously, there is no effect on bank financing.

High-potential firms with larger pledgeable earnings choose bank financing while firms with lesser potential and lower debt capacity must approach VC financing. Given their monitoring expertise, VCs are able to finance start-ups that could not get financed by standard banks alone, and thus boost entry of innovative firms. Using the short-hand notation $f_j = f(q_j)$ in evaluating (13), we find the number of start-ups changing by $dE = -q_m f_m \cdot \hat{q}_m$. The mass of bank-financed firms changes by $dE_b = -q_b f_b \cdot \hat{q}_b$. A lower cut-off q_m implies more entry at the lower margin while a lower cut-off q_b means that some firms switch from VC to bank financing. The mass of VC-backed companies is affected on both margins and may rise or fall, $dE_m = dE - dE_b$. Using (23) yields

$$
\begin{aligned}
dE_b &= \mu_{vb} q_b f_b \cdot \hat{v} + \mu_{\sigma b} q_b f_b \cdot \hat{\sigma} - \mu_{\phi b} q_b f_b \cdot \hat{\phi}, \\
dE &= \mu_{vm} q_m f_m \cdot \hat{v} + \mu_{\sigma m} q_m f_m \cdot \hat{\sigma} - \mu_{\phi m} q_m f_m \cdot \hat{\phi} - \mu_{bm} q_m f_m \cdot \hat{b}, \qquad (24) \\
dE_m &= (\mu_{vm} q_m f_m - \mu_{vb} q_b f_b) \cdot \hat{v} + (\mu_{\sigma m} q_m f_m - \mu_{\sigma b} q_b f_b) \cdot \hat{\sigma} \\
&: \; - \left(\mu_{\phi m} q_m f_m - \mu_{\phi b} q_b f_b\right) \cdot \hat{\phi} - \mu_{bm} q_m f_m \cdot \hat{b}.
\end{aligned}
$$

The heterogeneity of late-stage firms is a result not only of deliberate financing choices but also depends on whether R&D yields high or low earnings during the start-up period. Whatever its financing choice, each firm may end up either cash-rich or cash-poor. Shares change by $ds_{\ell j} = -ds_{hj}$. Taking the differential of (13) gives $ds_{hb} = (s_{hb} - q_b) \frac{q_b f_b}{E_b} \hat{q}_b$ and $ds_{hm} = (s_{hm} - q_m) \frac{q_m f_m}{E_m} \hat{q}_m + (q_b - s_{hm}) \frac{q_b f_b}{E_m} \hat{q}_b$.[13] Substituting (23) thus yields

$$
\begin{aligned}
ds_{hm} &= -\lambda_{vm} \cdot \hat{v} + \lambda_{\phi m} \cdot \hat{\phi} - \lambda_{\sigma m} \cdot \hat{\sigma} + \lambda_{bm} \cdot \hat{b}, \qquad (25) \\
ds_{hb} &= -\lambda_{vb} \cdot \hat{v} + \lambda_{\phi b} \cdot \hat{\phi} - \lambda_{\sigma b} \cdot \hat{\sigma},
\end{aligned}
$$

where coefficients are defined positive,

$$
\begin{aligned}
&\lambda_{vm} \equiv (s_{hm} - q_m) \tfrac{q_m f_m}{E_m} \mu_{mv} + (q_b - s_{hm}) \tfrac{q_b f_b}{E_m} \mu_{bv}, \quad \lambda_{vb} \equiv (s_{hb} - q_b) \tfrac{q_b f_b}{E_b} \mu_{vb}, \\
&\lambda_{\phi m} \equiv (s_{hm} - q_m) \tfrac{q_m f_m}{E_m} \mu_{\phi m} + (q_b - s_{hm}) \tfrac{q_b f_b}{E_m} \mu_{\phi b}, \quad \lambda_{\phi b} \equiv (s_{hb} - q_b) \tfrac{q_b f_b}{E_b} \mu_{\phi b}, \\
&\lambda_{\sigma m} \equiv (s_{hm} - q_m) \tfrac{q_m f_m}{E_m} \mu_{\sigma m} + (q_b - s_{hm}) \tfrac{q_b f_b}{E_m} \mu_{\sigma b}, \quad \lambda_{\sigma b} \equiv (s_{hb} - q_b) \tfrac{q_b f_b}{E_b} \mu_{\sigma b}, \\
&\lambda_{bm} \equiv (s_{hm} - q_m) \tfrac{q_m f_m}{E_m} \mu_{bm}.
\end{aligned}
$$

[13] By $q_b - s_{hm} = \int_{q_m}^{q_b} (q_b - q) \, dF(q) / E_m > 0$ and $s_{hm} - q_m = \int_{q_m}^{q_b} (q - q_m) \, dF(q) / E_m > 0$, we have $q_b > s_{hm} > q_m$.

A higher price reduces both cut-offs and shifts down the interval $[q_m, q_b]$, leading to a lower average value s_{hm} as well, i.e., the average probability of a good R&D outcome and, thereby, the share of highly profitable among all VC-backed companies falls. The same holds for the R&D subsidy and better investor protection (lower ϕ). A more efficient VC industry (lower b) manages financing additional firms with weaker potential which similarly reduces the share of highly profitable companies among all VC-backed firms.

The value of VC-backed firms changes by $d\Pi_M = vp\theta_M\hat{v} + kd\sigma + p\sum_j s_{jm}d\pi_{jm} + p\nabla_m ds_{mh}$, see (15). It obviously rises with early-stage earnings due to an increased price, a larger R&D subsidy, and with higher profits from late-stage investment. Expected rent also rises if there is a larger share of cash-rich, highly profitable firms among all VC-backed companies. Using (21), (25) and $I_M = \sum_j s_{jm}I_{jm}$ and doing similar steps for $d\Pi_B$ yields

$$\begin{aligned} d\Pi_M =& \; p\left[v\theta_M + \pi_M + \varepsilon_{vm}s_{\ell m}\pi_{\ell m} - \lambda_{vm}\nabla_m\right]\hat{v} + p\nabla_m\lambda_{bm}\hat{b} \\ -& \; p\left[\varepsilon_\phi s_{\ell m}\pi_{\ell m} - \lambda_{\phi m}\nabla_m\right]\hat{\phi} + p\left[\varepsilon_{\sigma m}s_{\ell m}\pi_{\ell m} + k/p - \lambda_{\sigma m}\nabla_m\right]\hat{\sigma}, \\ d\Pi_B =& \; p\left[v\theta_B + \pi_B + \varepsilon_{vb}s_{\ell b}\pi_{\ell b} - \lambda_{vb}\nabla_b\right]\hat{v} \\ -& \; p\left[\varepsilon_\phi s_{\ell b}\pi_{\ell b} - \lambda_{\phi b}\nabla_b\right]\hat{\phi} + p\left[\varepsilon_{\sigma b}s_{\ell b}\pi_{\ell b} + k/p - \lambda_{\sigma b}\nabla_b\right]\hat{\sigma}. \end{aligned} \tag{26}$$

The compositional effect works in the opposite direction. For example, better investor protection (lower ϕ) relaxes the financing constraint on late-stage investment of cash-poor firms, allowing firms to generate a larger surplus which boosts the expected rent when the firm is started up. The institutional improvement also encourages entry. Since profits of marginal firms are below average, the share of highly profitable firms in each group falls and thereby erodes the expected rent of start-ups. The overall effect is ambiguous. The exception is a higher productivity of VC financing (lower b) which leads to more entry without any further effect. Expected rents decline since marginal entrants push down the average profitability in each group.

4.2 Demand, Supply and Welfare

Aggregate Income: In deriving income and demand, we need to compute the impact on the government budget in (18). Starting from the untaxed equilibrium, we have

$$Z \cdot dt_Z + v^* (C_E - X_E) \cdot d\tau = kE \cdot d\sigma. \tag{27}$$

Aggregate income in (17) changes in line with the total, rent $\Pi_E = \Pi_M E_m + \Pi_B E_b$, and taxes, $dY = d\Pi_E - Z \cdot dt_Z$. Using (24) and (26) and rearranging yields

$$\begin{aligned} dY = \; & v^* (C_E - X_E) \cdot d\tau - [\Pi_M q_m f_m \mu_{bm} - p\nabla_m \lambda_{bm} E_m] \cdot \hat{b} \\ + \; & [p (v\theta_E + \pi_E) + \\ & \textstyle\sum_f (\varepsilon_{vf} s_{\ell f} \pi_{\ell f} - \lambda_{vf} \nabla_f) pE_f + \Pi_M q_m f_m \mu_{vm} + (\Pi_B - \Pi_M) q_b f_b \mu_{vb} \Big] \cdot \hat{v} \\ + \; & \Big[\textstyle\sum_f [\varepsilon_{\sigma f} s_{\ell f} \pi_{\ell f} - \lambda_{\sigma f} \nabla_f] pE_f + \Pi_M q_m f_m \mu_{\sigma m} + (\Pi_B - \Pi_M) q_b f_b \mu_{\sigma b}\Big] \cdot \hat{\sigma} \\ + \; & \Big[\textstyle\sum_f [\varepsilon_{\phi} s_{\ell f} \pi_{\ell f} - \lambda_{\phi f} \nabla_f] pE_f + \Pi_M q_m f_m \mu_{\phi m} + (\Pi_B - \Pi_M) q_b f_b \mu_{\phi b}\Big] \cdot \hat{\phi}. \end{aligned} \tag{28}$$

In the coefficient for the output price, the first bracket reflects the direct effects on the value of intermediate and late-stage earnings. In the second bracket, the first term shows the profit gain due to induced late-stage investment while the second term points to a compositional effect. By improving access to bank credit and thereby shifting down the upper threshold, a higher price reduces the share of highly productive firms among all bank-financed ones and boosts the share of less productive ones, $ds_{hb} = -\lambda_{vb} \cdot \hat{v} = -ds_{\ell b}$. This reduces income in proportion to the earnings differential ∇_b. A higher price shifts down the range of VC-backed firms on both ends which again implies, among all VC-backed firms, a larger share of less productive ones at the expense of highly profitable firms. Income declines in proportion to ∇_m. The last two terms capture how the changing composition of VC- and bank-financed firms affects aggregate income. A higher price reduces the lower threshold $\hat{q}_m = -\mu_{vm}\hat{v}$ and attracts entry of VC-backed firms which add an average rent Π_M per entrant. A declining upper threshold $\hat{q}_b = -\mu_{vb}\hat{v}$ indicates that some firms switch from VC to bank financing and thereby obtain a higher rent $\Pi_B > \Pi_M$ which again adds to aggregate income.

Similar interpretations apply to the R&D subsidy: it stimulates income by inducing more expansion investment of constrained firms with an excess return on investment; the share of less productive firms among all VC-backed and bank-financed firms rises and thereby reduces income; it boosts aggregate profits by stimulating entry of VC-backed firms, and by switching some firms from VC to cheaper bank financing; and finally, the R&D subsidy and the tax used to finance it cancel out in the aggregate. The effects of increasing investor protection (lower ϕ) and an R&D subsidy are much the same, except for the direct tax effect. Finally, VC maturation (lower b) improves access to capital. Hence, it affects only the lower entry margin but does not affect the banking margin. It adds average profits of additional VC-backed firms, but looses income since the share of cash-poor firms among all VC-backed companies rises.

Noting $\pi_E = vgI_E$ as well as $X_E = p\left(\theta_E + gI_E\right)$ and $\eta_s \equiv vX_E/Y$ yields

$$\hat{Y} = \left(\eta_s + \zeta_{yv}\right) \cdot \hat{v} + \zeta_{y\sigma} \cdot \hat{\sigma} - \zeta_{y\phi} \cdot \hat{\phi} - \zeta_{yb} \cdot \hat{b} + \left(\eta - \eta_s\right) \cdot \hat{\tau}. \tag{29}$$

Appendix B lists the coefficients and shows in (B.4) that they are all positive.

Demand for innovative goods depends on aggregate income and relative prices. With constant shares, $vC_E = \eta Y$, consumer demand changes by $\hat{C}_E = \hat{Y} - \hat{v}$ or

$$\hat{C}_E = -\left(1 - \eta_s - \zeta_{yv}\right) \cdot \hat{v} + \zeta_{y\sigma} \cdot \hat{\sigma} - \zeta_{y\phi} \cdot \hat{\phi} - \zeta_{yb} \cdot \hat{b} + \left(\eta - \eta_s\right) \cdot \hat{\tau}. \tag{30}$$

Aggregate Supply: Industry output results from a two-stage investment process and is defined as $X_E = p\left[\theta_E + gI_E\right]$. By (14), the change in mature firms' investment reflects scale and composition effects, $dI_E = E_m \cdot dI_M + E_b \cdot dI_B + I_M \cdot dE_m + I_B \cdot dE_b$. Since only cash-poor firms are constrained while cash-rich firms invest at the first-best level $\bar{I}$, we have $dI_M = s_{\ell m} dI_{\ell m} + \left(\bar{I} - I_{\ell m}\right) ds_{hm}$, and similarly for dI_B. Substituting (20) and (25) yields $dI_M = \left[s_{\ell m} I_{\ell m} \varepsilon_{vm} - \left(\bar{I} - I_{\ell m}\right) \lambda_{vm}\right] \cdot \hat{v}$, and similarly for other shocks. The first term indicates that a higher price boosts the scale of cash-poor firms, leading to an increase in average investment among all VC-backed firms. Since a higher price allows more firms to finance with cheaper bank credit, VC financing is limited to weaker firms.

When the share of cash-poor firms grows, more VC-backed firms get restricted to a lower scale of investment. This composition effect in the second term reduces average investment of VC backed firms, making the total effect ambiguous. Finally, a higher price raises the mass of bank-financed firms in (24), $dE_b = \mu_{vb} q_b f_b \cdot \hat{v}$, while the mass of VC-backed firms changes ambiguously, $dE_m = (\mu_{vm} q_m f_m - \mu_{vb} q_b f_b) \cdot \hat{v}$. A higher price attracts more start-ups which are all VC financed at the margin. On the other hand, some VC¨-backed firms switch to bank financing, thereby reducing the mass of VC-backed firms. Similar interpretations apply to other shocks. Putting all together, Appendix C calculates the change in aggregate late-stage investment,

$$\hat{I}_E = \zeta_{iv} \cdot \hat{v} + \zeta_{i\sigma} \cdot \hat{\sigma} - \zeta_{i\phi} \cdot \hat{\phi} - \zeta_{ib} \cdot \hat{b}, \tag{31}$$

where coefficients are all positive, see (C.4).[14]

Output of young firms changes by $d\theta_E = \theta_M \cdot dE_m + \theta_B \cdot dE_b + E_m \cdot d\theta_M + E_b \cdot d\theta_B$. An increasing innovative goods price allows more firms to access bank credit, augments the mass of bank-financed firms and boosts output by $\theta_B dE_b$, see (24). On the other hand, when more of the low-quality firms switch to bank financing, average productivity declines by $d\theta_B = (\theta_h - \theta_\ell)\, ds_{hb}$, see (25), which shrinks output by $E_b d\theta_B$. The same holds for VC backed firms, except that the mass of them changes ambiguously since there are more start-ups in need of VC but some of them switch to bank financing. Appendix C calculates

$$\hat{\theta}_E = \zeta_{\theta v} \cdot \hat{v} + \zeta_{\theta\sigma} \cdot \hat{\sigma} - \zeta_{\theta\phi} \cdot \hat{\phi} - \zeta_{\theta b} \cdot \hat{b}, \tag{32}$$

where coefficients are defined in (C.6) and are all positive.

Aggregate supply changes by $\hat{X}_E = \frac{p\theta_E}{X_E}\hat{\theta}_E + \frac{gpI_E}{X_E}\hat{I}_E$, reflecting output changes of young and mature firms. Output rises with a larger scale of mature firms and entry of new start-ups. Since marginal entrants have lower innovation potential in the sense that a high R&D outcome is less likely, the share of high-performing firms declines (see 24 and 25), and so does average productivity. Taking all together from results above, the supply response to

[14] In the first-best case, $\zeta_{iv} = \bar{I} q_b f_b \mu_{vb}/I_E$ and $\zeta_{i\sigma} = \bar{I} q_b f_b \mu_{\sigma b}/I_E$, while $\zeta_{i\phi} = \zeta_{ib} = 0$.

various shocks is

$$\hat{X}_E = \zeta_{xv} \cdot \hat{v} + \zeta_{x\sigma} \cdot \hat{\sigma} - \zeta_{x\phi} \cdot \hat{\phi} - \zeta_{xb} \cdot \hat{b}, \tag{33}$$

where coefficients are all defined positive and reported in (C.7) of Appendix C.

A country's trade structure is characterized by excess demand for innovative goods, $\xi \equiv C_E - X_E$. Defining $\hat{\xi} \equiv vd\xi/Y$ yields $\hat{\xi} = \eta\hat{C}_E - \eta_s\hat{X}_E$, or

$$\hat{\xi} = -\xi_v \cdot \hat{v} - \xi_\sigma \cdot \hat{\sigma} + \xi_\phi \cdot \hat{\phi} + \xi_b \cdot \hat{b} + (\eta - \eta_s)\, \eta \cdot \hat{\tau}, \tag{34}$$

where coefficients are given in (D.1) Appendix D. An increase in the world price expands supply and restricts demand which raises a country's trade surplus in the innovative sector. An R&D subsidy boosts supply and demand. Since the supply effect is relatively large and the demand effect is small, the net effect is positive, meaning that the subsidy reduces excess demand and creates a trade surplus in innovative goods. Appendix D shows that the ξ-elasticities are positive if the equilibrium is close to the first-best allocation.

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

$$\hat{U} = \left[\zeta_{yv} - (\eta - \eta_s)\right] \cdot \hat{v} + \zeta_{y\sigma} \cdot \hat{\sigma} - \zeta_{y\phi} \cdot \hat{\phi} - \zeta_{yb} \cdot \hat{b} + (\eta - \eta_s) \cdot \hat{\tau}. \tag{35}$$

In the absence of market frictions, investor protection and VC play no role, and coefficients ζ_{yv} and $\zeta_{y\sigma}$ are zero, see the discussion of (B.1) in Appendix B. In the first-best case, $\hat{U} = -(\eta - \eta_s)(\hat{v} - \hat{\tau})$. A higher price reduces welfare of an import country with $\eta > \eta_s$ due to a negative terms-of-trade effect.[15] In the distorted economy, a higher price strengthens pledgeable income, relaxes financing constraints and allows firms to realize unexploited investment opportunities with positive net value and magnifies national income and welfare by $\zeta_{yv} > 0$, see (B.4). A small R&D subsidy similarly boosts income

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

and welfare on two margins. It relaxes the financing constraints on R&D investments of new entrants and on equipment investment of cash-poor firms in the expansion stage. Financial sector development, as measured by a higher monitoring productivity of VCs ($\hat{b} < 0$), improves marginal firms' access to external financing of R&D investments. Better investor protection ($\hat{\phi} < 0$) similarly raises welfare by strengthening debt capacity of late-stage firms with little cash which allows them to undertake unexpoited investments with positive net value.

4.3 Policy Intervention

The following propositions summarize the consequences of seemingly different areas of policy intervention in a small open economy. We first turn to classical trade policy, consisting here of protection by raising tariffs. Import tariffs on innovative goods raise the domestic price and generate tax revenue which is channeled back to the private sector and raises disposable income in a non-distortive way, see (18).

Proposition 1 ***(Protection)*** *In a small open economy, a higher price boosts investment, output and profits of all firms, and relatively more so in constrained, cash-poor firms. It thereby induces VC-backed entry into the innovate sector and leads firms with intermediate profit potential to switch from VC to bank financing. It expands aggregate supply and reduces the trade deficit in innovative goods. In the presence of capital market frictions, protection boosts income and national welfare.*

The statements can be verified by the comparative static results in the preceding two subsections. In a small open economy facing a fixed world price v^*, import tariffs raise the domestic price one to one, $\hat{v} = \hat{\tau}$. A higher price boosts earnings of start-ups and late-stage firms. Late-stage firms thus inherit higher internal funds from the prior start-up phase and can self-finance a larger part of expansion investment. With higher pledgeable earnings, cash-poor firms are able to scale up expansion investment while cash-rich firms continue to invest at the optimal scale. In allowing cash-poor firms to exploit profitable investment opportunities to a larger extent, a higher price boosts their profits relatively more than profits of cash-rich firms, see (20)-(21). Stronger profits in the mature stage boost continuation values of all start-ups which relaxes financing constraints in (9) and (11). In consequence, additional firms at the lower margin can get started with VC. However, some firms with intermediate profit potential no longer require VC and switch to cheaper bank financing, see (23)-(24). The overall number of VC-backed firms may thus increase or decrease. Although the mass of VC-backed firms might decline, the key role of VC is to improve access to capital, allowing more firms with strictly positive net value to get started. Relaxing financing constraints on mature, cash-poor firms and on early-stage innovative start-ups importantly adds to aggregate income. Income gains in (28) stem from several sources: tariffs raise revenue; a higher price directly boosts firm earnings in both stages; strengthening pledgeable earnings boosts profits by better exploiting profitable opportunities in both investment stages; and switching from VC to bank financing economizes on VC costs and thereby also adds to income. All in all, using $\hat{v} = \hat{\tau}$ in (29), aggregate income rises by $\hat{Y} = \left(\eta + \zeta_{yv}\right) \cdot \hat{\tau}$. Consumer demand for innovative goods may rise or fall since income increases but the higher price shifts demand towards standard goods.

Small tariffs boost aggregate supply by raising aggregate investment and output of young and mature firms. With details discussed in deriving (31), late-stage investment rises since more firms are created and survive to the mature stage, and since better access to capital allows cash-poor firms to scale up investment. Aggregate output of young firms also rises, mainly since more firms are created even though marginal firms have a lower earnings potential, see (32). Adding up over the cross-section of firms, a higher tariff boosts aggregate domestic supply. Substituting (D.1) into (34) and using $\hat{v} = \hat{\tau}$, we find that protection reduces the country's trade deficit in innovative goods, $\hat{\xi} = -\left[\left(1 - \eta - \zeta_{yv}\right)\eta + \zeta_{xv}\eta_s\right] \cdot \hat{\tau} < 0$, if the equilibrium is close to the first-best case (so that ζ_{yv} is small). Since a higher domestic price boosts pledgeable earnings, it facilitates investments with positive net value, yielding a welfare gain of $\hat{U} = \zeta_{yv} \cdot \hat{\tau}$, see (35). In a first-best equilibrium without capital market frictions, a small tariff would entail a zero welfare gain to the first order (i.e., $\zeta_{yv} = 0$ by the analysis following B.1). Capital market problems might justify a small level of protection to help 'infant industries' with innovative and financially dependent firms that are unable to exploit their growth opportunities.

While at least a small degree of protection might help to relax financing constraints and yield welfare gains, other policies may target more directly the root of the problem. We first turn to the role of R&D subsidies.

Proposition 2 ***(R&D Subsidy)*** *In a small open economy with a fixed price, an R&D subsidy boosts investment, output and profits of all firms, and relatively more so in constrained, cash-poor firms. It thereby induces VC-backed entry into the innovative sector and leads firms with intermediate profit potential to switch from VC to bank financing. It expands aggregate supply and reduces the trade deficit in innovative goods. In the presence of capital market frictions, an R&D subsidy boosts income and national welfare.*

The direct effect of an R&D subsidy is to co-finance early-stage R&D spending and thereby facilitate entry into the innovative sector. This is a standard effect that unfolds in an undistorted economy as well. In the presence of capital market frictions, we identify an additional, 'long-lasting' effect of R&D subsidies. When a firm survives the start-up period, it inherits more internal funds including the subsidy on early-stage R&D spending. Since investment of mature, cash-poor firms is sensitive to cash-flow, the subsidy also encourages subsequent expansion investment of those firms, allowing them to exploit profit opportunities to a larger extent, see (20)-(21). This second effect is not present with cash-rich, unconstrained firms but strengthens profits when a firm ends up being short of own funds. Prior to the realization of R&D risk leading to high or low early-stage output, young firms anticipate higher profits in the unfavorable event. Therefore, the R&D subsidy boosts the continuation value of start-ups which additionally relaxes the financing constraint on R&D investment. Start-up activity, which is VC-financed at the margin, picks up. Not only are there more start-ups, all with strictly positive net value, but some of them also switch from VC to cheaper bank financing. For all those reasons, aggregate income rises, see (28)-(29), and so does demand for innovative goods. Aggregate supply rises on the extensive and intensive margins, and the trade deficit shrinks (if capital market distortions are not too severe). The R&D subsidy boosts national welfare, reflecting the income gains from relaxing financing constraints on entry as well as expansion investment of cash-poor firms, $\hat{U} = \zeta_{y\sigma} \cdot \hat{\sigma} > 0$. The welfare gain of a small R&D subsidy would be zero in the first-best case ($\zeta_{y\sigma}^{*} = 0$, see the discussion of B.1), but is strictly positive when access to credit is limited.

The existence of financing constraints might be rooted in weak institutions like bad accounting rules and reporting standards, little investor protection and other weaknesses in corporate governance. Another important reason is a rather immature financial sector which performs little effective monitoring and oversight of firms and is unable to facilitate firms' access to external funding. These problems are particularly damaging in financially dependent innovative industries. We associate higher institutional quality with a *lower* value of ϕ. As accounting and reporting standards improve, outsiders observe more precisely a mature firm's true resources, and managing owners will find it more difficult to hide and divert earnings. We record the following results.

Proposition 3 ***(Institutional Improvement)*** *In a small open economy with a fixed price, institutional development boosts late-stage investment, output and profits of constrained firms with little cash. It thereby induces VC-backed entry into the innovative sector and leads firms with intermediate profit potential to switch from VC to bank financing. It expands aggregate supply and reduces the trade deficit in innovative goods. Institutional improvement boosts income and national welfare.*

When insiders find it more difficult to hide earnings from external investors, a firm's pleadgeable income rises which improves access to external funds. Expansion investment, output and profit of cash-poor firms increase. Cash-rich firms are not affected since the financing constraint is slack so that diversion cannot threaten external investors. They continue to invest at the optimal scale. Higher profits in the bad state when R&D yields a less favorable outcome, boost the continuation value of young firms and therefore relax the financing constraint on R&D spending. Better access to early-stage financing not only attracts more entry which is VC-financed at the margin, but also allows some firms with intermediate profit potential to switch from VC to cheaper bank financing, see (23). Aggregate income and demand for innovative goods increase when more firms with strictly positive net value get started and firms are better able to exploit profitable investment opportunities in the expansion stage. On the supply side, relaxing financing constraints on entry and subsequent firm growth boosts aggregate investment and output. Aggregate supply expands by more than demand and, thus, shrinks the trade deficit in innovative goods, see (34). By relaxing financing constraints on expansion investment of cash-poor mature firms and on early-stage R&D investment, institutional development ($\hat{\phi} < 0$) boosts national welfare by $\hat{U} = -\zeta_{y\phi} \cdot \hat{\phi} > 0$.

Finally, we turn to financial sector development, meaning that VC firms become more effective in monitoring young firms without adding to monitoring costs. The demand for VC is driven by the financing needs of young innovative firms which are unable to obtain bank financing of highly risky R&D investment. The role of VC is to raise a firm's debt capacity by better monitoring and control. VC thus performs a certification role. Observing that a firm attracts active VC, standard banks can trust in good corporate governance and will be able to lend more as well. By this mechanism, a mature VC sector improves access to external financing and boosts start-up activity of young innovative firms with strictly positive net value. VC is more costly since the monitoring activity must be compensated. Hence, firms with high profit potential and large debt capacity can do with pure bank financing and do not demand VC. In consequence, they do not directly benefit from financial development. The relative advantage of VC is in financing profitable firms with weak debt capacity. The following statements are verified by tracing the effects of $\hat{b}$ in Sections 4.1-4.2, setting other shocks to zero. Note that this scenario has no counterpart in an undistorted economy since demand for monitoring capital arises only if a part of firms has severe problems to get funded.

Proposition 4 ***(Venture Capital)*** *More productive monitoring boosts a firm's debt capacity and relaxes the constraint on R&D investment. With a fixed output price, mature firms are not directly affected. More active VC financing adds profitable innovative firms to the economy, thereby expanding aggregate supply. Although income and demand grow as well, financial development reduces the trade deficit with innovative goods. National welfare increases as more profitable firms get started to exploit investment opportunties.*

Referring to the analytical results in Sections 4.1-4.2, VC improves access to capital but does not directly add value to firms. Given constant monitoring costs, a more productive VC sector ($\hat{b} < 0$) raises the debt capacity of young entrepreneurial firms but does not directly affect earnings and investment of mature firms. There is thus no immediate effect on continuation values of young firms, see (20)-(22). The scenario does not affect the upper threshold where firms are indifferent between bank and VC financing. The number of bank-financed firms remains unchanged, see (9) and (23). However, by (11) and (23), better VC oversight boosts the debt capacity of innovative firms with relatively weaker profit potential. More active VC financing thus promotes entry into the innovative sector to reap positive profits that could not get exploited if only standard bank financing were available. The number of VC-financed firms rises, and so does the total number of firms, see (24). Since all firms earn strictly positive profits, aggregate income and, in turn, demand for innovative goods rise. In stimulating investment on the extensive margin, VC development boosts aggregate supply and finally reduces the trade deficit. This illustrates the role of active VC financing and financial development as a source of comparative advantage in innovative goods.[16] A more productive VC sector also enhances national welfare by financing additional innovative start-ups with strictly positive, unexploited profit potential. The welfare gain amounts to $\hat{U} = -\zeta_{yb} \cdot \hat{b} > 0$, where the coefficient is proportional to the profit $\Pi_m(q_m) > 0$ of the marginal start-up, see (B.4) in Appendix B.

[16] Suppose all countries were symmetric. Let us improve only one country's financial development in that world. Then, this country would become a net exporter of R&D intensive goods and the other countries would become net importers thereof.

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 countervailing 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.[17] When the home economy is importing, the domestic price rises with tariff protection, $v = (1+\tau)\, v^*$, relative to the common world price v^*. At the outset, $\tau = 0$ and $v = v^*$. World market equilibrium requires $d\xi + \sum_j d\xi^j = 0$ where ξ^j is excess demand in other countries. Multiply by $v = v^*$, divide by world GDP, use country j's GDP share $\omega^j \equiv Y^j/(Y + \sum_j Y^j)$, implying $\omega + \sum_j \omega^j = 1$, and define $\hat{\xi}^j \equiv v^* d\xi^j / Y^j$. Global market clearing entails $\omega\hat{\xi} + \sum_j \omega^j \hat{\xi}^j = 0$ and pins down the impact on the common price. Protection relates domestic and foreign prices by $\hat{v} = \hat{v}^* + \hat{\tau}$. Using this, domestic excess demand changes as in (34), while excess demand in foreign countries changes by $\hat{\xi}^j = -\xi_v^j \cdot \hat{v}^*$ which yields

$$\hat{v}^* = -\omega \frac{\xi_v - (\eta - \eta_s)\,\eta}{\xi_v^*} \cdot \hat{\tau} - \omega \frac{\xi_\sigma}{\xi_v^*} \cdot \hat{\sigma} + \omega \frac{\xi_\phi}{\xi_v^*} \cdot \hat{\phi} + \omega \frac{\xi_b}{\xi_v^*} \cdot \hat{b}, \quad \xi_v^* \equiv \omega \xi_v + \textstyle\sum_j \omega^j \xi_v^j, \qquad (36)$$

where ξ_v^* is the GDP-weighted average of individual countries' elasticities. By the same argument as in (34) and (D.1) in Appendix D, the term $\xi_v - (\eta - \eta_s)\,\eta = \left(1 - \eta - \zeta_{y,v}\right)\eta + \zeta_{x,v}\eta_s$ is positive if financing distortions are small. The small economy case results if the number of countries n gets large. The symmetric case with $\xi_v^* = n\omega\xi_v$ leads to $\hat{v}^* = -\left(\xi_\sigma / \left(n\xi_v\right)\right) \cdot \hat{\sigma}$, for example. As $n \to \infty$ (implying $\omega \to 0$), an isolated shock to the home country has a negligible impact on the world price. In a closed economy with $n = \omega = 1$, protection is irrelevant and the equilibrium price follows from $\hat{\xi} = 0$ in (34).

If the home economy introduces an import tariff, it raises the domestic price above the world price level, $\hat{v} = \hat{v}^* + \hat{\tau}$. The trade deficit shrinks which creates excess supply on

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

the world market and depresses the world price, see (36). Since $\omega\xi_v/\xi_v^* < 1$, protection raises the domestic price, but less so than in a small open economy,

$$\hat{v} = \left(1 - \omega \frac{\xi_v - (\eta - \eta_s)\,\eta}{\xi_v^*}\right) \cdot \hat{\tau} > 0. \tag{37}$$

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

Since all shocks by assumption occur at home, foreign countries are only affected by a change in the common price v^*. Replacing v by v^* in Section 3 and noting $\tau^j = 0$ yields the adjustment in a foreign country j.[18]

Proposition 5 ***(Protection Spillovers)*** *(a) Import protection reduces the world price* v^* *and thereby discourages foreign investment, output and profits. It thereby discourages VC-backed entry into the innovate sector and forces foreign firms with intermediate profit potential to switch from bank to VC financing. Although income declines, it likely raises demand as consumers switch to innovative goods. It restricts aggregate supply and reduces (magnifies) foreign trade surpluses (deficits) in innovative goods. (b) Domestic protection tightens foreign financing constraints. Welfare of foreign export nations* ($\eta < \eta_s$) *strongly falls since the negative terms-of-trade effect is reinforced by tightening financing conditions. Welfare of foreign import nations* ($\eta > \eta_s$) *changes ambiguously since the positive terms-of-trade effect may be offset by firms becoming more constrained.*

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

Proposition 6 ***(Protection and 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.*

[18] International welfare results from protection are similar to Egger and Keuschnigg (2011). That paper did not consider the effects of early-stage R&D on late-stage investment and the coexistence of constrained and unconstrained firms. Further, the analysis of R&D subsidies and financial development is new.

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 1 applies. Being financially constrained, it benefits from protection, since the policy boosts investment with a strictly positive net value, raising welfare. Since the home country gains while no foreign economy looses in this scenario, also world welfare rises.

Instead of protection, the home economy could subsidize R&D to become more competitive in the innovative industry. In short, Proposition 2 continues to hold but effects are dampened. Increased supply and the reduction of the trade deficit drive down the world price of innovative goods which feeds back negatively on the home economy. Much like with protection, foreign welfare depends on how terms-of-trade effects interact with financing distortions. For the sake of brevity, we do not repeat the analysis but rather turn to policies for institutional and financial development which directly aim to reduce financing frictions which are particularly damaging in financially dependent innovative industries. We associate higher institutional quality with a *lower* value of ϕ. As accounting and reporting standards improve, managing owners find it more difficult to hide and divert earnings. More effective monitoring and better oversight (lower b) boost the debt capacity for early-stage R&D investment so that more firms with positive net value can get started. Financial and institutional development thus trigger a supply side expansion and drive down the world price of the innovative good by $\hat{v}^* = \left(\omega\xi_\phi/\xi_v^*\right)\cdot\hat{\phi} + \left(\omega\xi_b/\xi_v^*\right)\cdot\hat{b} < 0$, see (36), leading to terms-of-trade effects. The price erosion feeds back negatively on domestic equilibrium. Welfare changes by $\hat{U} = \left[\zeta_{yv} - (\eta - \eta_s)\right]\cdot\hat{v}^* - \zeta_{y\phi}\cdot\hat{\phi} - \zeta_{yb}\cdot\hat{b}$. Since the home economy is a net importer by assumption, the terms-of-trade effect equal to $-(\eta - \eta_s)\,\hat{v}^*$ actually reinforces the welfare gains from policies towards institutional and financial development while the negative feedback effect on domestic income captured by $\zeta_{yv}\hat{v}^*$ offsets them. Given the results of Section 4, we can state:

Proposition 7 ***(Institutional and Financial Development)*** *(a) The reduction in the world price dampens the supply-side expansion. Compared to a small open economy, the gains in investment, output and R&D driven start-up activity are smaller. The trade* *deficit in innovative goods shrinks by less. Domestic welfare gains are smaller or larger than in a small open economy. (b) The lower world price reduces foreign investments, output, profits and VC-backed entry into the innovate sector. It shrinks (magnifies) foreign trade surpluses (deficits) in innovative goods. Welfare in foreign export nations strongly falls due to tighter financing constraints and deteriorating terms of trade while welfare changes ambiguously in foreign import nations.*

It is unlikely that the negative feedback could overturn the direct effects of an R&D subsidy as they obtain in a small open economy. Obviously, the smaller the share ω of the home economy in world GDP, the smaller is the impact on the world price v^*, and the smaller is the negative feedback.

6 Discussion

Our model emphasizes access to credit but also has implications for the financial structure of firms. At start-up, entrepreneurs are endowed with own funds A_0, and must finance part of R&D investment with outside funds. Bank-financed firms require a residual credit of $D_b = (1 - \sigma) k - A_0$ and must repay $R_b = D_b/p$. Any residual earnings in excess of repayment go to entrepreneurs. An R&D subsidy reduces the share of outside credit in total R&D investment. All other shocks leave the financial structure unchanged and exclusively affect the extensive margin of bank financing, see (23). The same logic applies to VC-backed firms, although their financial structure is richer. Optimal contracts set the incentive compatible repayment of VCs equal to $R_m = \gamma / (p - p_L)$ and set outside VC financing equal to $D_m = pR_m - k_m$, leaving zero profits to VCs. Hence, R&D investment is financed with own funds A_0, venture capital D_m, and residual bank credit $D_{bm} = (1 - \sigma) k - A_0 - D_m$. An R&D subsidy reduces investment needs, leading to lower residual bank financing while own funding and VC funding remain constant. Again, all other shocks have no effect on financial structure but affect the extensive margin of VC financing as in (23). These results are due to the fact that the scale of early-stage

R&D investment is assumed constant; R&D investment uses only the standard good; and intermediaries are competitive and earn zero profits.

At the industry level, the model has rich implications for the relative number of VC- and bank-financed firms. An increase in the price of innovative goods, for example, shifts down both financing margins in (23), leading to an unambiguous increase in the number of bank-financed firms. In general, there are no clear-cut results for the number of VC-backed start-ups, reflecting offsetting 'inflows' and 'outflows' into VC financing. A higher price strengthens pledgeable earnings, allowing some additional firms with low expected value to get started with venture capital. On the other hand, some firms with stronger prospects switch to cheaper bank financing, leaving an overall ambiguous effect on the number of VC-backed firms. These changes reflect the comparative advantage of VC in financing the weakest firms with the largest financing problem that cannot go on with bank financing alone. Firms with higher debt capacity should go with bank financing to economize on costly monitoring. The economically relevant role of VC is to to finance projects with strictly positive net value that could otherwise not get started.

In the mature stage of a firm's life-cycle, the scale of investment is variable up to a maximum value $\bar{I}$ where returns drop to zero. In our model, cash-rich firms are able to invest at the optimal scale $\bar{I}$ while cash-poor firms with lower earnings at the end of the start-up phase are constrained. An institutional improvement (lower ϕ) relaxes the financing constraint and leads to a larger investment scale, see (7). Institutional reform thus raises the share of external funds in total investment cost.[19] Other shocks do not affect financing shares but may scale up or down investment levels. This leads to larger or smaller profit levels $\pi_{\ell f} = vgI_{\ell f}$ and feeds back on the extensive margins of early-stage R&D investment by affecting continuation values of start-ups.

A final comment relates to the role of VC in financing early-stage R&D. In our model, VC is the market solution to overcome funding problems of profitable firms at the lower margin of R&D profitability. An alternative role is to add value to new entrepreneurial

[19] External credit is $vI-A$ with financing shares $(vI-A)/(vI) = (1-\phi)G$ and $A/(vI) = 1-(1-\phi)G$.

firms which is valuable for all start-ups in the innovative sector. Strategic advice, monitoring and control by VCs raises the success probability and thereby the expected value of a VC backed start-up. These productive services come at an extra cost, leading to two possible cases (see Tirole, 2006, Chapter 9 and Figure 9.2). First, if monitoring costs are small, VC adds value and, in addition, boosts pledgeable earnings. Hence, all incumbent firms are able to attract VC financing to boost their value, plus some additional entrants at the lower margin of the earnings potential are able to do so. There would be no market segmentation between bank and VC financing. Second, VC adds value but is costly so that pledgeable earnings are reduced. In this case, firms with lower earnings potential cannot afford these advisory services and must go with bank financing alone. VC financing is available only to firms with the highest profit potential which benefit from the extra value added of VC.

7 Conclusions

To investigate the interaction between innovation, finance and trade, we have proposed a multi-country, two-sector model with capital and entrepreneurial labor. Entry into the innovative sector requires a fixed R&D investment followed by variable expansion investment if the firm survives the start-up period. Firms differ in the profit potential created by initial R&D. In high potential firms, R&D very likely yields high output and earnings at the end of the start-up period. Weaker firms are relatively more likely to end up with little own earnings. Low-potential firms will only be able to get financed if VC is available, with banks supplying residual credit. The role of VC is to finance start-ups with the most severe financing problems which have strictly positive net value but cannot get funded with bank credit alone. High potential firms have access to bank credit and can economize on more costly VC funds. In either financing mode, earnings at the end of the start-up period turn out either high or low, leaving firms with higher or lower own funds to enter the expansion phase. Cash-rich firms will be able to finance at the optimal scale while cash-poor firms are constrained and cannot fully exploit their investment opportunity. Early-stage policy interventions such as R&D subsidies have long-lasting effects on late-stage investment. Policies designed to improve access to capital in the early and late stage of a firm's life-cycle, or for young and old firms in the cross-section, can importantly strengthen a country's comparative advantage in innovative industries.

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

Appendix

A. Financial Contract Type q is observable but not yet realized. Starting with bank financing, the continuation value of an R&D project is $W_b(q)$. We suppress index q. An entrepreneur has wealth A_0, puts A into her firm and invests $A_0 - A$ on the capital market, yielding a zero surplus. The entrepreneur's program is to maximize end-of-period value s.t. IC_e (the entrepreneurial incentive constraint), PC_e (the entrepreneurial participation constraint), and PC_b (the banks' participation constraint)

$$\begin{aligned}\Pi_b = \;& \max_{R_b,A} p\left(W_b - R_b\right) - A + \mu_e\left[p\left(W_b - R_b\right) - B\right] \\ + \;& \lambda_b\left[pR_b - (1+\rho)\left((1-\sigma)k - A\right)\right] + \lambda_e\left[A_0 - A\right].\end{aligned} \tag{A.1}$$

We assume that the bank earns an excess return ρ on its credit $(1-\sigma)k - A$, and let $\rho \to 0$. Necessary conditions, complemented by Kuhn-Tucker conditions, are

$$\lambda_b = 1 + \mu_e, \quad \lambda_e = (1+\rho)\lambda_b - 1. \tag{A.2}$$

The first condition $\lambda_b \geq 1$ means that PC_b (the banks' participation constraint) always binds. Using this, the shadow price of the entrepreneur's participation condition is $\lambda_e = (1+\rho)(1+\mu_e) - 1$.

Bank Financing – Case 1, $\mu_e = 0$: Given a required credit and repayment, a firm with high continuation value $W_b(q)$ has large pledgeable earnings so that IC_e is slack. This implies $\lambda_b = 1$ and $\lambda_e = \rho > 0$. The firm pledges all own assets, $A = A_0$, to reduce the need for credit which is more expensive than own funds (as long as $\rho > 0$) and would reduce the firm's own surplus. Letting $\rho \to 0$, the solution becomes $pR_b = (1-\sigma)k - A_0$ (binding PC_b) and $\Pi_b = pW_b - (1-\sigma)k$, see (3). Inspecting IC_e shows that the constraint must become binding for some critical low type q_b since the continution value $W_b(q)$ falls with lower types, see the discussion of (9).

Bank Financing – Case 2, $\mu_e > 0$: Given a credit and repayment, a less profitable firm $W_b(q_b)$ of low type q_b has little pledgeable earnings so that IC_e is binding. This implies $\lambda_e > 0$, even if $\rho = 0$. The firm pledges all own assets, $A = A_0$, to relax the binding incentive constraint, by reducing the need for external credit, cutting repayment, and raising pledgeable income. Letting $\rho \to 0$, yields the same solution as noted in (3).

For low types $q < q_b$, exclusive bank financing is not available anymore. Given the setup in Section 2.3, a firm with continuation value $W_m(q)$ proposes a value maximizing contract for bank and VC financing

$$\begin{aligned} \Pi_m = \; & \max_{R_{bm}, R_m, D_m} p(W_m - R_m - R_{bm}) - A_0 \\ + \; & \mu_e [p(W_m - R_m - R_{bm}) - b] + \lambda_b [pR_{bm} - (1-\sigma)k + A_0 + D_m] \\ + \; & \mu_m [pR_m - \gamma] + \lambda_m [pR_m - k_m - (1+\rho) D_m]. \end{aligned} \tag{A.3}$$

Using the same arguments as above, we use the fact that the entrepreneur commits all own assets to get better access to external funds $A = A_0$. Optimality conditions, augmented by Kuhn-Tucker conditions, are

$$\lambda_b = 1 + \mu_e, \quad 1 + \mu_e = \mu_m + \lambda_m, \quad \lambda_b = (1+\rho)\lambda_m. \tag{A.4}$$

VC Financing – Case 1, $\mu_e = 0$: Given repayments and monitoring, a firm with higher continuation value $W_m(q)$ has larger pledgeable earnings so that IC_e may be slack. This implies $\lambda_b = 1$ and, by the last condition, $\lambda_m > 0$. Hence, both participation constraints are binding. Firms want to repay as little as possible to maximize their own surplus. The optimality conditions are related by $\mu_m + \lambda_m = 1 + \mu_e = \lambda_b = (1+\rho)\lambda_m$ which implies $\mu_m = \rho\lambda_m > 0$. As long as there is an infinitesimal excess return ρ, i.e., venture capital is scarce and more costly, IC_m is binding as well. Firms propose a minimum VC repayment that still guarantees monitoring (binding IC_m), thereby scale down the extent of VC financing (binding PC_m), and replace it with cheaper bank financing (binding PC_b). Letting $\rho \to 0$ establishes the solution noted in the paragraph prior to (11). Inspecting IC_e shows that the constraint must become binding for some critical low type q_m since the continution value $W_m(q)$ falls with lower types, see the discussion of (11).

VC Financing – Case 2, $\mu_e > 0$: Given a required credit and repayment, a less profitable firm $W_m(q_m)$ of low type q_m has little pledgeable earnings so that IC_e is binding. This implies $\lambda_b > 0$, $\lambda_m > 0$, and $\mu_m = \rho\lambda_m > 0$. The same logic as before applies.

B. Aggregate Income The coefficients in (29) are defined as

$$\begin{aligned}
\zeta_{yv} &\equiv \textstyle\sum_f \frac{[\varepsilon_{vf} s_{\ell f}\pi_{\ell f} - \lambda_{vf}\nabla_f]\, pE_f}{Y} + \frac{\Pi_M q_m f_m \mu_{vm} + (\Pi_B - \Pi_M)\, q_b f_b \mu_{vb}}{Y}, \\
\zeta_{y\sigma} &\equiv \textstyle\sum_f \frac{[\varepsilon_{\sigma f} s_{\ell f}\pi_{\ell f} - \lambda_{\sigma f}\nabla_f]\, pE_f}{Y} + \frac{\Pi_M q_m f_m \mu_{\sigma m} + (\Pi_B - \Pi_M)\, q_b f_b \mu_{\sigma b}}{Y}, \\
\zeta_{y\phi} &\equiv \textstyle\sum_f \frac{[\varepsilon_{\phi} s_{\ell f}\pi_{\ell f} - \lambda_{\phi f}\nabla_f]\, pE_f}{Y} + \frac{\Pi_M q_m f_m \mu_{\phi m} + (\Pi_B - \Pi_M)\, q_b f_b \mu_{\phi b}}{Y}, \\
\zeta_{yb} &\equiv \frac{\Pi_M q_m f_m \mu_{bm} - p\nabla_m \lambda_{bm} E_m}{Y}.
\end{aligned} \tag{B.1}$$

We first show that the coefficients are zero in the absence of distortions. In a first-best world without credit constraints, VC serves no role and is absent. Investment is set at the optimal value: $s_{jm} = E_m = 0$, $I_{jb} = \bar{I}$, $\pi_{jb} = \bar{\pi} = vg\bar{I}$, $\varepsilon_{vf} = 0$, and $\nabla_b = v(\theta_h - \theta_\ell)$. By free entry, $k = pW_b(q_b) = p[v\theta_\ell + \bar{\pi} + q_b\nabla_b]$, implying $\mu_{vb} = W_b(q_b)/(q_b\nabla_b)$ and $\lambda_{vb} = (s_{hb} - q_b)\frac{f_b}{E_b} q_b\mu_{vb}$. By (15), $\Pi_B = p[v\theta_\ell + \bar{\pi} + s_{hb}\nabla_b] - k = (s_{hb} - q_b)\, p\nabla_b$. Hence, $Y\zeta_{yv}^* = \Pi_B q_b f_b \mu_{vb} - \lambda_{vb}\nabla_b pE_b = [\Pi_B - (s_{hb} - q_b)\, p\nabla_b]\, f_b q_b \mu_{vb} = 0$. By the same steps, evaluating $\zeta_{y\sigma}$ in the first-best case and using $\lambda_{\sigma b} = (s_{hb} - q_b)\frac{q_b f_b}{E_b}\mu_{\sigma b}$ yields $Y\zeta_{y\sigma}^* = 0$ and

$Y\zeta^*_{y\phi} = 0$ in the same way. In the absence of capital market frictions, parameters ϕ and b relating to investor protection and VC efficiency play no role.

We now evaluate the coefficients in the untaxed equilibrium with distortions. Noting (2) and $\Pi_m(q_m) = pW_m(q_m) - k - k_m$, we can write

$$\begin{aligned} \Pi_M &= p\left[v\theta_\ell + \pi_{\ell m} + s_{hm}\nabla_m\right] - k - k_m = \Pi_m(q_m) + (s_{hm} - q_m)\, p\nabla_m, \\ \Pi_B &= p\left[v\theta_\ell + \pi_{\ell b} + s_{hb}\nabla_b\right] - k = \Pi_b(q_b) + (s_{hb} - q_b)\, p\nabla_b. \end{aligned} \tag{B.2}$$

Substitute λ_{bm} from (25) to get

$$Y\zeta_{yb} = \Pi_M q_m f_m \mu_{bm} - p\lambda_{bm}\nabla_m E_m = \Pi_m(q_m)\cdot q_m f_m \mu_{bm} > 0. \tag{B.3}$$

Credit rationing implies that the marginal entrant is constrained and earns an excess return $\Pi_m(q_m) > 0$, see (11). Substituting the λ-coefficients, doing the same steps, and noting that bank-financed firms have more internal funds, $\pi_{jb} > \pi_{jm}$, yields

$$\begin{aligned} \zeta_{yv} &= \tfrac{p\sum_f \varepsilon_v s_{\ell f}\pi_{\ell f}E_f + \Pi_m(q_m)q_m f_m \mu_{mv} + [q_b(\pi_{hb}-\pi_{hm})p + (1-q_b)(\pi_{\ell b}-\pi_{\ell m})p + k_m]q_b f_b \mu_{vb}}{Y} > 0, \\ \zeta_{y\sigma} &= \tfrac{p\sum_f \varepsilon_{\sigma f} s_{\ell f}\pi_{\ell f}E_f + \Pi_m(q_m)q_m f_m \mu_{\sigma m} + [q_b(\pi_{hb}-\pi_{hm})p + (1-q_b)(\pi_{\ell b}-\pi_{\ell m})p + k_m]q_b f_b \mu_{\sigma b}}{Y} > 0, \\ \zeta_{y\phi} &\equiv \tfrac{p\sum_f \varepsilon_{\phi} s_{\ell f}\pi_{\ell f}E_f + \Pi_m(q_m)q_m f_m \mu_{\phi m} + [q_b(\pi_{hb}-\pi_{hm})p + (1-q_b)(\pi_{\ell b}-\pi_{\ell m})p + k_m]q_b f_b \mu_{\phi b}}{Y} > 0, \\ \zeta_{yb} &= \tfrac{\Pi_m(q_m)q_m f_m \mu_{bm}}{Y} > 0. \end{aligned} \tag{B.4}$$

C. Aggregate Supply Aggregate supply is $X_E = p\left[\theta_E + gI_E\right]$. Mature-firm investment changes by $dI_E = E_m \cdot dI_M + E_b \cdot dI_B + I_M \cdot dE_m + I_B \cdot dE_b$. Since investment of cash-rich firms is fixed by $\bar{I}$, we have $dI_M = s_{\ell m} dI_{\ell m} + \left(\bar{I} - I_{\ell m}\right) ds_{hm}$, and similarly for dI_B. Using (20) and (25), average investment of VC- and bank-financed firms changes by[20]

$$\begin{aligned} dI_M &= \left[s_{\ell m}I_{\ell m}\varepsilon_{vm} - \left(\bar{I} - I_{\ell m}\right)\lambda_{vm}\right]\cdot\hat{v} - \left[s_{\ell m}I_{\ell m}\varepsilon_{\phi} - \left(\bar{I} - I_{\ell m}\right)\lambda_{\phi m}\right]\cdot\hat{\phi} \\ &: \; + \left[s_{\ell m}I_{\ell m}\varepsilon_{\sigma m} - \left(\bar{I} - I_{\ell m}\right)\lambda_{\sigma m}\right]\cdot\hat{\sigma} + \left(\bar{I} - I_{\ell m}\right)\lambda_{bm}\cdot\hat{b}, \\ dI_B &= \left[s_{\ell b}I_{\ell b}\varepsilon_{vb} - \left(\bar{I} - I_{\ell b}\right)\lambda_{vb}\right]\cdot\hat{v} - \left[s_{\ell b}I_{\ell b}\varepsilon_{\phi} - \left(\bar{I} - I_{\ell b}\right)\lambda_{\phi b}\right]\cdot\hat{\phi} \\ &: \; + \left[s_{\ell b}I_{\ell b}\varepsilon_{\sigma b} - \left(\bar{I} - I_{\ell b}\right)\lambda_{\sigma b}\right]\cdot\hat{\sigma}. \end{aligned} \tag{C.1}$$

[20] In the first-best, $I_{jf} = \bar{I}$, and $I_M = I_B = \bar{I}$ are fixed.

Using this and noting the changing masses of VC-backed and bank-financed firms in (24), average total investment changes by

$$\begin{aligned}
&dI_E = \left[I_M q_m f_m \mu_{vm} + (I_B - I_M)\, q_b f_b \mu_{vb} + \textstyle\sum_f \left[s_{\ell f} I_{\ell f} \varepsilon_{vf} - \left(\bar{I} - I_{\ell f}\right) \lambda_{vf}\right] E_f\right] \hat{v} \\
&+ \left[I_M q_m f_m \mu_{\sigma m} + (I_B - I_M)\, q_b f_b \mu_{\sigma b} + \textstyle\sum_f \left[s_{\ell f} I_{\ell f} \varepsilon_{\sigma f} - \left(\bar{I} - I_{\ell f}\right) \lambda_{\sigma f}\right] E_f\right] \cdot \hat{\sigma} \\
&- \left[I_M q_m f_m \mu_{\phi m} + (I_B - I_M)\, q_b f_b \mu_{\phi b} + \textstyle\sum_f \left[s_{\ell f} I_{\ell f} \varepsilon_{\phi} - \left(\bar{I} - I_{\ell f}\right) \lambda_{\phi f}\right] E_f\right] \cdot \hat{\phi} \\
&- \left[I_M q_m f_m \mu_{bm} - \left(\bar{I} - I_{\ell m}\right) \lambda_{bm} E_m\right] \cdot \hat{b}.
\end{aligned} \tag{C.2}$$

For the next step, use $s_{hf} + s_{\ell f} = 1$, substitute $I_M = \sum_j s_{jm} I_{jm}$ and I_B, and get the following relationships, where $\bar{I}_{mm} < \bar{I}_{bm} < \bar{I}_{bb} < \bar{I}$:

$$\begin{aligned}
I_M - \left(\bar{I} - I_{\ell m}\right)(s_{hm} - q_m) &= q_m \bar{I} + (1 - q_m)\, I_{\ell m} \equiv \bar{I}_{mm} > 0, \\
I_M - \left(\bar{I} - I_{\ell m}\right)(s_{hm} - q_b) &= q_b \bar{I} + (1 - q_b)\, I_{\ell m} \equiv \bar{I}_{bm} > 0, \\
I_B - \left(\bar{I} - I_{\ell b}\right)(s_{hb} - q_b) &= q_b \bar{I} + (1 - q_b)\, I_{\ell b} \equiv \bar{I}_{bb} > 0.
\end{aligned} \tag{C.3}$$

Substituting the λ-coefficients in (C.2) and using (C.3) yields $\hat{I}_E = \zeta_{iv} \cdot \hat{v} + \zeta_{i\sigma} \cdot \hat{\sigma} - \zeta_{i\phi} \cdot \hat{\phi} - \zeta_{ib} \cdot \hat{b}$ as in (31), where the coefficients are[21]

$$\begin{aligned}
\zeta_{iv} &\equiv \left[\textstyle\sum_f s_{\ell f} I_{\ell f} \varepsilon_{vf} E_f + \bar{I}_{mm} q_m f_m \mu_{mv} + \left(\bar{I}_{bb} - \bar{I}_{bm}\right) q_b f_b \mu_{vb}\right] / I_E > 0, \\
\zeta_{i\sigma} &\equiv \left[\textstyle\sum_f s_{\ell f} I_{\ell f} \varepsilon_{\sigma f} + \bar{I}_{mm} q_m f_m \mu_{\sigma m} + \left(\bar{I}_{bb} - \bar{I}_{bm}\right) q_b f_b \mu_{\sigma b}\right] / I_E > 0, \\
\zeta_{i\phi} &\equiv \left[\textstyle\sum_f s_{\ell f} I_{\ell f} \varepsilon_{\phi} E_f + \bar{I}_{mm} q_m f_m \mu_{\phi m} + \left(\bar{I}_{bb} - \bar{I}_{bm}\right) q_b f_b \mu_{\phi b}\right] / I_E > 0, \\
\zeta_{ib} &\equiv \bar{I}_{mm} q_m f_m \mu_{bm} / I_E > 0.
\end{aligned} \tag{C.4}$$

Output of young firms changes by $d\theta_E = \theta_M \cdot dE_m + \theta_B \cdot dE_b + E_m \cdot d\theta_M + E_b \cdot d\theta_B$. Substituting (25) in $d\theta_M = (\theta_h - \theta_\ell)\, ds_{hm}$, and similarly in $d\theta_B$, and using (24) yields

$$\begin{aligned}
d\theta_E &= \left[\theta_M q_m f_m \mu_{vm} + (\theta_B - \theta_M)\, q_b f_b \mu_{vb} - (\theta_h - \theta_\ell)\,(E_m \lambda_{vm} + E_b \lambda_{vb})\right] \cdot \hat{v} \\
&: \; + \left[\theta_M q_m f_m \mu_{\sigma m} + (\theta_B - \theta_M)\, q_b f_b \mu_{\sigma b} - (\theta_h - \theta_\ell)\,(E_m \lambda_{\sigma m} + E_b \lambda_{\sigma b})\right] \cdot \hat{\sigma} \\
&: \; - \left[\theta_M q_m f_m \mu_{\phi m} + (\theta_B - \theta_M)\, q_b f_b \mu_{\phi b} - (\theta_h - \theta_\ell)\,(E_m \lambda_{\phi m} + E_b \lambda_{\phi b})\right] \cdot \hat{\phi} \\
&: \; - \left[\theta_M q_m f_m \mu_{bm} - (\theta_h - \theta_\ell)\, E_m \lambda_{bm}\right] \cdot \hat{b}
\end{aligned} \tag{C.5}$$

[21] In the first-best case, $\bar{I}_{bb} = \bar{I}$ and $\bar{I}_{mm} = \bar{I}_{bm} = \varepsilon_{vf} = 0$, leaving $\zeta_{iv} = \bar{I} q_b f_b \mu_{vb} / I_E$ and $\zeta_{i\sigma} = \bar{I} q_b f_b \mu_{\sigma b} / I_E$, while $\zeta_{i\phi} = \zeta_{ib} = 0$ due to $\mu_{\phi b} = \mu_{bm} = 0$.

Using the λ-coefficients, θ_M and θ_B as well as $\theta_B - (\theta_h - \theta_\ell)(s_{hb} - q_b) = q_b\theta_h + (1-q_b)\theta_\ell$ yields $\hat{\theta}_E = \zeta_{\theta v} \cdot \hat{v} + \zeta_{\theta\sigma} \cdot \hat{\sigma} - \zeta_{\theta\phi} \cdot \hat{\phi} - \zeta_{\theta b} \cdot \hat{b}$, where the coefficients are defined as[22]

$$\begin{aligned} \zeta_{\theta v} &\equiv \frac{q_m\theta_h + (1-q_m)\theta_\ell}{\theta_E} q_m f_m \mu_{mv}, \quad \zeta_{\theta\sigma} \equiv \frac{q_m\theta_h + (1-q_m)\theta_\ell}{\theta_E} q_m f_m \mu_{\sigma m}, \\ \zeta_{\theta\phi} &\equiv \frac{q_m\theta_h + (1-q_m)\theta_\ell}{\theta_E} q_m f_m \mu_{\phi m}, \quad \zeta_{\theta b} \equiv \frac{q_m\theta_h + (1-q_m)\theta_\ell}{\theta_E} q_m f_m \mu_{bm}. \end{aligned} \tag{C.6}$$

The main text derives in (33) the effects on aggregate supply, $\hat{X}_E = \frac{p\theta_E}{X_E}\hat{\theta}_E + \frac{gpI_E}{X_E}\hat{I}_E$. Using (31)-(32), supply changes by $\hat{X}_E = \zeta_{xv} \cdot \hat{v} + \zeta_{x\sigma} \cdot \hat{\sigma} - \zeta_{x\phi} \cdot \hat{\phi} - \zeta_{xb} \cdot \hat{b}$ where coefficients are all positive and defined as

$$\begin{aligned} \zeta_{xv} &\equiv \frac{p\theta_E}{X_E}\zeta_{\theta v} + \frac{gpI_E}{X_E}\zeta_{iv}, \quad \zeta_{x\sigma} \equiv \frac{p\theta_E}{X_E}\zeta_{\theta\sigma} + \frac{gpI_E}{X_E}\zeta_{i\sigma}, \\ \zeta_{x\phi} &\equiv \frac{p\theta_E}{X_E}\zeta_{\theta\phi} + \frac{gpI_E}{X_E}\zeta_{i\phi}, \quad \zeta_{xb} \equiv \frac{p\theta_E}{X_E}\zeta_{\theta b} + \frac{gpI_E}{X_E}\zeta_{ib}. \end{aligned} \tag{C.7}$$

D. Trade Balance A country's trade structure is characterized by excess demand, $\xi \equiv C_E - X_E$. Defining $\hat{\xi} \equiv vd\xi/Y$ yields $\hat{\xi} = \eta\hat{C}_E - \eta_s\hat{X}_E$. Substituting (30) and (33) yields $\hat{\xi} = -\xi_v \cdot \hat{v} - \xi_\sigma \cdot \hat{\sigma} + \xi_\phi \cdot \hat{\phi} + \xi_b \cdot \hat{b} + (\eta - \eta_s)\eta \cdot d\tau$ as in (34), where, using demand and supply elasticities, the coefficients are

$$\begin{aligned} \xi_v &\equiv \left(1 - \eta_s - \zeta_{yv}\right)\eta + \zeta_{xv}\eta_s > 0, \quad \xi_\sigma \equiv \zeta_{x\sigma}\eta_s - \zeta_{y\sigma}\eta > 0, \\ \xi_\phi &\equiv \zeta_{x\phi}\eta_s - \zeta_{y\phi}\eta > 0, \quad \xi_b \equiv \zeta_{xb}\eta_s - \zeta_{yb}\eta > 0. \end{aligned} \tag{D.1}$$

In the first-best case, ζ_{yv} and $\zeta_{y\sigma}$ are zero (see B.1) while ζ_{xv} and $\zeta_{x\sigma}$ are positive (see C.7). Letting the equilibrium approach the first-best case guarantees $\xi_v > 0$ and $\xi_\sigma > 0$. Next, we show that $\xi_b > 0$ in the distorted equilibrium. Substitute coefficients, note

[22] Note that early-stage earnings θ_j are independent of the financing mode. Aggregate output θ_E of young firms thus depends on entry at the lower margin, e.g., $dE = q_m f_m \mu_{vm}\hat{v}$, where the marginal firm adds expected output $q_m\theta_h + (1-q_m)\theta_\ell$. In the first-best case, there is no role for VC. The marginal firm is bank-financed. Thus, aggregate output changes by $\hat{\theta}_E = \zeta_{\theta v}\hat{v} + \zeta_{\theta\sigma}\hat{\sigma}$, with coefficients $\zeta_{\theta v} \equiv [q_b\theta_h + (1-q_b)\theta_\ell]\, q_b f_b \mu_{bv}/\theta_E$ and $\zeta_{\theta\sigma} \equiv [q_b\theta_h + (1-q_b)\theta_\ell]\, q_b f_b \mu_{\sigma b}/\theta_E$.

$\eta_s \equiv vX_E/Y$ and $\eta \equiv vC_E/Y$ in $\xi_b = \zeta_{xb}\eta_s - \zeta_{yb}\eta$ and use the definition in (4) to get

$$\begin{aligned} \xi_b &= \left[p\frac{q_m\left(\theta_h + g\bar{I}\right) + (1-q_m)(\theta_\ell + gI_{\ell m})}{X_E} \cdot \eta_s - \frac{\Pi_m(q_m)}{Y} \cdot \eta \right] q_m f_m \mu_{bm} \\ &= \frac{(1-\eta)\Pi_m(q_m) + k + k_m}{Y} q_m f_m \mu_{bm} > 0. \end{aligned} \quad \text{(D.2)}$$

Finally, evaluate $\xi_\phi \equiv \zeta_{x\phi}\eta_s - \zeta_{y\phi}\eta$ and note $\pi_{jf} = vgI_{jf}$ and $q_m\bar{I} + (1-q_m)I_{\ell m} \equiv \bar{I}_{mm}$. After some tedious manipulations,

$$\begin{aligned} \xi_\phi &= \frac{(1-\eta)p\sum_f s_{\ell f}\pi_{\ell f}\varepsilon_\phi E_f}{Y} + \frac{(1-\eta)\Pi_m(q_m) + k + k_m}{Y} q_m f_m \mu_{\phi m} \\ &: +\frac{pvg\left(\bar{I}_{bb} - \bar{I}_{bm}\right) - \eta\left(p\left[q_b\left(\pi_{hb} - \pi_{hm}\right) + (1-q_b)\left(\pi_{\ell b} - \pi_{\ell m}\right)\right] + k_m\right)}{Y} q_b f_b \mu_{\phi b}. \end{aligned} \quad \text{(D.3)}$$

Use $\bar{I}_{bb}$, $\bar{I}_{bm}$, $\pi_{jf} = vgI_{jf}$ to get $vg\left(\bar{I}_{bb} - \bar{I}_{bm}\right) = q_b\left(\pi_{hb} - \pi_{hm}\right) + (1-q_b)\left(\pi_{\ell b} - \pi_{\ell m}\right)$. Expand by $v\theta_j - v\theta_j$ and get $vg\left(\bar{I}_{bb} - \bar{I}_{bm}\right) = W_b(q_b) - W_m(q_b) > 0$. If evaluated for the same type, the continuation value with VC is less than with bank financing. Hence,

$$\begin{aligned} \xi_\phi &= \frac{(1-\eta)p\sum_f s_{\ell f}\pi_{\ell f}\varepsilon_\phi E_f}{Y} + \frac{(1-\eta)\Pi_m(q_m) + k + k_m}{Y} q_m f_m \mu_{\phi m} \\ &: +\frac{(1-\eta)p\left[W_b(q_b) - W_m(q_b)\right] - \eta k_m}{Y} q_b f_b \mu_{\phi b} > 0. \end{aligned} \quad \text{(D.4)}$$

The only reason why mature-firm profit depends on the financing mode is the extra cost k_m of VC. Hence, if $k_m \to 0$, then $\pi_{jb} \to \pi_{jm}$ so that the second line above disappears, leaving an overall positive sign of the coefficient by the first line. A sufficient condition for $\xi_\phi > 0$ is thus that k_m is small (which is perfectly compatible with Assumptions 1 and 3). Alternatively, one may assume η to be relatively small.

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