行政院國家科學委員會補助專題研究計畫 ■成果報告 □期中進度報告

金融發展與經濟成長之因果與非線性關係：金融政策的角色

計畫類別：■個別型計畫　□整合型計畫
計畫編號：NSC 97-2628-H-004-091-MY2
執行期間： 2008 年 08 月 01 日至 2010 年 12 月 31 日

執行機構及系所：國立台北大學/政治大學經濟學系

計畫主持人：洪福聲教授
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目錄

Explaining the nonlinear effects of financial development on economic growth

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Abstract

Using different indicators of financial development, recent empirical studies have discovered various patterns of nonlinearity in the relationship between financial development and economic growth. By adding consumption loans, which are nonproductive, into a standard model of asymmetric information, this paper generates a model that is able to replicate all possible nonlinear finance-growth relationships found in recent empirical studies.

Keywords: Asymmetric Information, Credit Rationing, Financial Development, Economic Growth

JEL Classification: G21; O41

Explaining the nonlinear effects of financial development on economic growth

1 Introduction

It has long been recognized that financial sectors have a significant bearing on economic growth (Goldsmith, 1969; McKinnon, 1973; Shaw, 1973). Although this view had been neglected for a period of almost twenty years, there has been a resurgence of interest in examining the relationship between finance and economic growth since the early 1990s. Theoretically, a recent study by Greenwood and Jovanovic (1990), for example, demonstrates that financial institutions that produce better information on firms and thus induce a more efficient allocation of capital investment can foster economic growth. Bencivenga and Smith (1991) highlight the role of financial intermediaries in mitigating individuals' liquidity risk, which increases illiquid investment (with a higher yield) in the economy and thereby promotes economic growth. Saint-Paul (1992) illustrates that the development of financial markets enables firms to diversify their profitability shocks arising from variations in demand and thereby induces firms to adopt a more specialized and productive technology. Empirically, King and Levine (1993a, b) and Levine, Loayza, and Beck (2000), among many others, find a strong positive correlation between financial development and economic growth.

After a positive finance-growth relationship has been confirmed, two strands of related empirical works have emerged. The first strand of empirical studies examines the finance-growth relationship across countries, time periods, or stages of economic development, finding that the finance-growth relationship is nonlinear. Examples include De Gregorios and Guidotti (1996), Deidda and Fattouh (2002), Rioja and Valev (2004), and Shen and Lee (2006). The second strand of literature focuses on the effects of financial development on private consumption, arguing that financial development may enhance private consumption, which further reduces an economy's total resources available for capital investment and hence leads to an adverse effect on economic growth. Examples include Jappelli and Pagano (1994) and Chan and Hu (1997). It

is worth noting that, as reviewed below, the first straind of studies, by using different indicators of financial development, have discovered various patterns of the nonlinearity between financial development and economic growth. Given the various patterns of the nonlinearity, it is nature to inquire which pattern of nonlinearity is more convincing. Such an issue has attracted some theoretical works (e.g., Bose anf Cothren, 1996; Deidda and Fattouh, 2002; Deidda, 2006) to develop models in explaining the nonlinear finance-growth relationships found by recent empirical works. Results, however, show that different theoretical studies yield different patterns of nonlinearity, leaving this issue unanswered.

If the finance-growth relationship is indeed nonlinear and the indicators of financial development employed by recent works are proper, then a theoretical model that is able to capture the nonlinear finance-growth relationship should be able to replicate all possible nonlinear relationships found by recent empirical works. This, however, is not accomplished. The purpose of this paper is to develop a theoretical model that can replicate all possible patterns of the nonlinearity between financial development and economic growth. Such a framework is imporant as it not only confirms the existence of this nonlinearity but also provides a convincing explanation to this relationship. In searching for such a framework, it is interesting to note that all aforementioned theoretical works visit this nonlinearity by focusing on how financial development influences capital invesment and, through this channel, economic growth. As such a setting cannot replicate all patterns of nonliearity found by recent empirical studies, this paper proposes to revist this nonlinarity by integrating the first straind of studies with the second straind. Specifically, we integrate both types of loans into a single framework: loans for investment purpose and loans for consumption purpose. Under this framework, financial development leads to two opposite effects on economic growth. On the one hand, financial development that facilitates loans for capital investment promotes economic growth, as Bose and Cothren (1996) and Deidda (2006). On the other hand, financial development may relax consumers' borrowing constraints and hence reduce total resources available for capital investment. This latter effect impedes capital investment and hence economic growth, as found by Jappelli and Pagano (1994) and Chan and

Hu (1997). The presence of these two opposite effects implies that the relationship between financial development and economic growth is determined by the relative magnitudes of these two opposite effects. It is further found that the relative magnitude of these two effects differ in different levels of financial development, which can be used to replicate all possible patterns of nonlinearity found by recent empirical works.

The remainder of this paper proceeds as follows. Section 2 reviews recent literature and presents the study plan of this paper. Section 3 presents the basic model and Section 4 describes the equilibrium loan contracts for the purpose of investment and consumption. In Section 5 we examine the nonlinear relationship between financial development and economic growth. Section 6 concludes.

2 Literature Review and a Study Plan

King and Levine (19993) have discovered a positive effect of financial development on economic growth from various indicators of financial development. By asserting that the ratio of bank credit in the private sector to GDP (termed as CREDIT) is a better indicator of financial development and by dividing countries into three groups according to their income levels, De Gregorio and Guidotti (1995) find that the positive effect of financial development on economic growth is much more significant in low- and middle-income countries than in high-income countries. Deidda and Fattouh (2002), on the other hand, utilize the ratio of currency plus demand and interest-bearing liabilities of banks and non-bank financial intermediation to GDP (termed as LLY) as the indicator of financial development. By dividing countries into two groups according to their income levels (i.e., high- and low-income countries), Deidda and Fattouh (2002) find that the relationship between financial development and economic growth is not significant in low-income countries but that only in high-income countries will financial development significantly promote economic growth. It is well recognized that high-income countries possess relatively

high levels of financial development compared with low-income countries.[1] As a result, the studies by Deidda and Fattouh (2002) and De Gregorio and Guidotti (1995) imply that the effect of financial development on economic growth is nonlinear, although they reach different conclusions by using different indicators for financial development and classify countries into different income groups.

While Deidda and Fattouh (2002) and De Gregorio and Guidotti (1995) confirm the existence of a nonlinear relatioship between financial development and economic growth, it is improper to draw conclusion on the finance-growth relationship from both studies as they use different indicators of financial development and classify countries into different groups. Recetly, Rioja and Valev (2004) employ both LLY and CREDIT as indicators of financial development and propose grouping countries into three categories according to *their levels of financial development,* instead of grouping countries by their income levels. They find a consistent, nonlinear relationship between financial development and economic growth from both LLY and CREDIT indicators. More specifically, Rioja and Valev (2004) find that the effect of financial development on economic growth is uncertain for countries with low levels of financial development. However, financial development significantly promotes economic growth for countries with intermediate levels of financial development. For countries with high levels of financial development, the finance-growth relationship is still positive. Nevertheless, the marginal impact of financial development on economic growth is higher for countries with intermediate levels of financial development than for those with high levels of financial development. If both CREDIT and LLY are proper indicators of financial development, then the study of Rioja and Valev (2004) seems more convincing than Deidda and Fattouh (2002) and De Gregorio and Guidotti (1995) because Rioja and Valev (2004) utilize both CREDIT and LLY as indicators of financial development and obtain a consistent relationship between finance and growth from both indicators. More recently, Shen and Lee (2006) also confirm this nonlinearity, as they employ different indicators

[1] By comparing 36 countries over a period of a century, Goldsmith (1969) finds that time periods with higher growth coincide with faster financial development. Thus, high income countries, which result from high growth over a long period, possess a high level of financial development. See also Fry (1995).

to measure banking as well as stock market development, and find that the relationship between banking development and economic growth exhibits an inverse U-shape. In other words, they find that banking development first promotes economic growth, until a level of banking development is reach after which further banking development decreases economic growth.

In light of recent empirical works, we may conclude that the relationship between financial development and economic growth is nonlinear. It is worth noting that some recent theoretical studies have attempted to capture this nonlinear relationship.[2] Nevertheless, each of these theoretical models focuses on a specific aspect of financial markets, which leads to different patterns of nonlinearity. Given this, it is also improper to draw conclusion from recent theoretical works. In this paper, we intend to explain the cause of this nonlinearity by developing a model that is general enough to replicate all possible nonlinear finance-growth relationshipd found by recent empirical works.

It has long been recognized that financial markets are characterized by a wide variety of informational imperfections and that financial development reduces transaction as well as information costs to the economy (King and Levine, 1993b; Fry, 1995; Rioja and Valev, 2004; among others).[3] From this point of view, it is natural to examine the finance-growth relationship in a model where asymmetric information exists in financial markets and financial institutions perform an intermediate role in terms of the transactions between lenders and borrowers. One paper that can potentially shed light on the nonlinear finance-growth relationship from this viewpoint is Bose and Cothren (1996, 1997). As is demonstrated by Bencivenga and Smith (1993), asymmetric information forces lenders to ration a fraction of borrowers to induce the self selection of borrowers. The presence of credit rationing holds back capital investment that decreases economic growth in a framework where capital investment creates an externality in relation to capital productivity (Romer, 1986). Bose and Cothren (1996) extend such a framework to demonstrate that, in addition to credit rationing, lenders may employ a costly screening technology to ac-

[2] Bose and Cothren (1996), Deidda and Fattouh (2002), Hung and Cothren (2002) and Deidda (2006) attempted to explain this nonlinear relationship. Nevertheless, their results are not consistent with Rioja and Valev (2004).

[3] The roles of financial development in affecting real activities are summarized by Levine (2004).

quire information related to the borrowers' ability to invest capital (where such expense can be attributed to information cost). Bose and Cothren (1996) show that credit rationing arises for those economies whose information costs are extremely high. For middle levels of information costs, lenders randomly employ credit rationing and costly technology to induce self selection (labeled as a mixed regime), with the probability of using the screening technology increasing along with a decrease in the information cost. Finally, lenders employ only the screening technology to induce self selection (labeled as a regime of screening) for countries with relatively low levels of information costs. It is worth noting that credit rationing disappears in the screening regime. In the mixed regime, financial development that increases the probability of screening reduces the extent of credit rationing. Bose and Cothren (1996) show that the increase in the probability of screening in the mixed regime has two opposite effects on capital investment and economic growth. First, it reduces credit rationing and hence promotes capital investment. Second, due to the increase in the probability of screening, it raises the amount of resources absorbed in the process of acquiring information and is therefore detrimental to economic growth. Only when the information cost is lower than a threshold level will financial development promote capital investment and economic growth.

As is believed, financial development is able to reduce the information cost. Hence, we may interpret a decrease in the screening cost as financial development (such as Ho and Wang, 2005). Under this interpretation, Bose and Cothren's (1996) analysis implies that there is a nonlinear relationship between financial development and economic growth. Specifically, economic growth is independent of financial development in the rationing regime, which arises for countries with high levels of information cost (i.e., for countries with low levels of financial development). For countries with middle levels of financial development, financial development increases the probability of screening, which may increase or decrease economic growth, depending on the two opposite effects aforementioned. In countries with relatively developed financial sectors, financial development unambiguously promotes growth. While the nonlinear finance-growth nexus in Bose and Cothren (1996) seems consistent with the one discovered by Deidda and Fattouh

(2002), it cannot capture the nonlinear finance-growth relationship found by Rioja and Valev (2004).

To yield a framework that can account for the nonlinear finance-growth relationship found by Rioja and Valev (2004), we modify Bose and Cothren (1996) in two directions. First, we focus on the rationing regime of Bose and Cothren (1996), as it has been found that credit rationing exists in countries at all levels of financial development.[4] Financial development in the rationing regime of Bose and Cothren (1996), however, has no effect on economic growth. To overcome this and to capture the fact that financial development reduces transaction as well as information costs, we assume that there are loan-processing costs in loan making and that the true outcome of borrowers' capital investments is private information. While the loan-processing cost corresponds to the transaction cost, the latter assumption indicates that lenders must expend some real resources to verify the borrowers' true outcome when they claim bankruptcy. As is well known in Diamond (1984), financial institutions such as banks arise to perform the role of delegated monitoring in this context. This monitoring cost is a type of information cost. As is common in the literature, we assume that financial development reduces both transaction and information costs. Under this interpretation, we find that financial development reduces the extent of credit rationing and thereby facilitates capital investment and economic growth. Moreover, due to the incentive constraint that results in credit rationing, this positive effect of financial development on economic growth declines along with financial development. This modification seems able to explain Rioja and Valev's (2004) finding that the positive effect of finance on growth is more significant in countries with intermediate levels of financial development than in those countries with high levels of financial development. However, it cannot explain why the effect of financial development on economic growth is uncertain for low levels of financial development (Rioja and Valev, 2004) as well as why financial development may have a negative impact on economic growth for countries with high levels of financial development (Shen and

[4] As already mentioned, credit rationing disappears in the screening regime, which arises in countries with developed financial sectors. This is not consistent with empirical studies. For example, Pagano (1989) provides evidence of credit rationing in the U.S.

Lee, 2006).

The second modification is to include loans for non-productive consumption. While most theoretical studies focus on loans for capital investment, Jappelli and Pagano (1994) examine the effect of credit rationing on economic growth from loans for non-productive consumption. More specifically, in a model where the credit rationing of consumption loans is exogenously given, Jappelli and Pagano (1994) show that an increase in the extent of credit rationing reduces banking resources allocated to consumers and thereby forces the economy to save more resources for capital investment. In a model where capital investment gives rise to an externality, the increase in the extent of credit rationing in consumption loans promotes growth. In this paper, we follow Bose and Cothren (1996) to endogenously obtain credit rationing in regard to consumption loans and add it to a framework modified from Bose and Cothren's (1996) rationing regime. By so doing, financial development in this context leads to two opposite effects on capital investment and economic growth. First, it reduces the extent of credit rationing in regard to loans for capital investment purpose and thereby promotes growth. Second, it also reduces the extent of credit rationing for loans to consumption, which, as is demonstrated by Jappelli and Pagano (1994), is detrimental to capital investment and economic growth.

In this model, the net effect of financial development on economic growth depends on the relative magnitudes of these two opposite effects. It is further found that the effect of investment loans is a concave function of the level of financial development while the effect of consumption loans is a U-shaped function of the level of financial development. From these, we find that this model can replicate all patterns of the nonlinear finance-growth relationships that are found in recent empirical works. For example, for countries with low levels of financial development, the effect of consumption loans may dominate or be dominated by that of investment loans, implying that the effect of financial development on economic growth is uncertain. For countries with intermediate levels of financial development, the effect of investment loans overwhelmingly dominates that of consumption loans, indicating that financial development significantly promotes economic growth. For countries with high levels of financial development, the effect of consump-

tion loans increases with the level of financial development. Thus, the effect of investment loans may again dominate or be dominated by that of consumption loans. If it still dominates the effect of consumption loans, then financial development still promotes growth. Nevertheless, this positive effect is less significant than that for countries with intermediate levels of financial development. This case is consistent with Rioja and Valev (2004).[5] Moreover, it is possible that the positive (*resp.* negative) effect of financial development dominates that of the negative (*resp.* positive) one for relatively low (*resp.* high) levels of financial development, leading to an inverse-U relationship between financial development and economic growth. This is the case found by Shen and Lee (2006). We also provide some numerical examples that generate the finance-growth relationships consistent with De Gregorio and Guidotti (1995) and Deidda and Fattouh (2002).

3 Model

Consider a model economy consisting of an infinite sequence of two-period-lived, overlapping generations plus a set of initial old agents present at $t = 1$.[6] Each generation is of identical size and composition, and contains two kinds of risk neutral agents: lenders and borrowers. Borrowers are further divided into two groups of equal size: entrepreneurs and consumers. For simplicity, each population of lenders and borrowers is normalized to n ($n > 1$) and 2, respectively.

3.1 *Behavior of Agents*

Young lenders and entrepreneurs are each endowed with a unit of labor, which is supplied inelastically at t to generate the wage rate w_t. Both lenders and entrepreneurs care only for old-age consumption; hence, they must save their young wage income for old-age consumption.

[5] Rioja and Valev (2004) offer some theoretical reasonings from different theoretical studies to justify their decision to divide countries into high-, middle-, and low-levels of financial development. However, it seems impossible to weave these different theoretical reasonings into a single framework.

[6] This is a modified model from Bencivenga and Smith (1993), Bose and Cothren (1996, 1997), and Capasso and Mavrotas (2003).

There are two technologies at t available for producing time-t+1 capital, which is the only means for saving in this economy. The first type of the technology is a traditional technology (or in short, the T technology) while the second type is an advanced technology (the A technology). Young entrepreneurs at t are capable of adopting either the T technology or the A technology to produce time-t+1 capital, which can be rented to firms in return for output at t+1. The adoption of the advanced technology, however, invloves some restrictions. The basic idea is to capture McKinnon's (1973, p. 12) observation that investments associated with the adoption of a markedly improved technology are characterized with indivisibility and requires the entrepreneur to borrow to finance discrete increases in investment expenditures. Moreover, borrowing under indivisibility must be accepted or rejected on an one-or-nothing basis (Mao, 1970). To replicate these observations, it is assumed that the adoption of the A technology at t requires exactly $\overline{m}w_t$ units of output, where $\overline{m}$ is greater than one so that external funds are needed for the entrepreneur to adopt the A technology. As will be clear, this assumption implies that a entrepreneur must borrow $\overline{m}w_t$ net of his own wage income to adopt the A technology or the entrepreneur's loan application is rejected. On the contrary, there is no requirement imposed on the input for adopting the T technology so that external financing is inessential.

Entrepreneurs are further divided into two types at birth: good-ability (type-g) and bad-ability (type-b) entrepreneurs. A λ fraction of entrepreneurs are of type-b while the remaining are of type-g. Entrepreneurs' types refer to their ability in operating the A and T technologies. Specifically, a type i ($i = g$, b) entrepreneur who obtains a loan (with a quantity of $\overline{m}w_t - w_t$) and adopts the A technology at t can produce Q units of time-t+1 capital with probability p_i. With probability $1 - p_i$, the adoption of the A technology fails and in this case the scrap value of investment is equal to s_i, $i = g$, b, units (consumption good) per unit of initial input. By assumption, $1 \geq p_g > p_b > 0$ and $s_g > s_b = 0$. Thus, a type-g entrepreneur has a better ability in adopting the A technology than a type-b entrepreneur, regardless of whether the adoption of the A technology is successful or not. Note that, if external funding is not available, then an entrepreneur will adopt the T technology by using her own wage income (i.e., the entrepreneur is

self-financed). A type-i entrepreneur who adopts the T technology with her own wage at t can produce $Q\varepsilon_i$, $\varepsilon_i < 1$, units of time-t+1 capital without uncertainty. It is assumed that $\varepsilon_g > \varepsilon_b$; hence, a type-$g$ entrepreneur also has a better ability in adopting the T technology than a type-b entrepreneur. As there is no restriction on the adoption of the T technology, young lenders also have access to the T technology. For simplicity, we assume that the young lenders' ability in adopting the T technology is as good as that of the type-b entrepreneurs; hence, lenders can convert a unit of time-t output into $Q\varepsilon_b$ units of time-t+1 capital by adopting the T technology.

Similar to entrepreneurs, consumers are divided into two types at birth: good-luck (type-g) and bad-luck (type-b) consumers. The consumers' type refers to the probability of obtaining x units of labor in their final period of life. Specifically, a type-i, i=g, b, consumer will be endowed with x units of labor with probability p_i in her old age. By assumption, $1 \geq p_g > p_b > 0$ so that a good-luck consumer has a higher probability of obtaining x units of the old-age labor endowment than a bad-luck one. A λ (*resp.* $1-\lambda$) fraction of consumers is of type-b (*resp.* type-g). Note that if a type-i consumer obtains her labor endowment, she will sell it to firms to generate wage income. Consumers care for both young- and old-age consumption, with the utility function of a generation-t young consumer being given as

$$c_t + \mu c_{t+1}, \ \mu > 0, \tag{1}$$

where c_t is consumption at the young age, c_{t+1} is consumption in old age, and μ is the discount factor. To induce borrowing, it is assumed that μ is sufficiently small; hence, if possible, each consumer intends to borrow all of her expected old-age wage income for young-age consumption.

Finally, it is assumed that each time-t old entrepreneur becomes a firm operator, which can employ k_t units of capital and L_t units of labor to produce output y_t (in the same period) according to the following technology:

$$y_t = B\overline{k}_t^{\eta} k_t^{\gamma} L_t^{1-\gamma}, \ B > 0, \ \gamma \in (0,1), \tag{2}$$

where $\overline{k}_t$ is the average per-firm capital stock. Capital depreciates fully after production. In

equilibrium, each firm will employ the same amount of capital; hence, $k_t = \overline{k}_t$. Moreover, following Bose and Cothren (1996) and Bose (2002), it is assumed that $\eta = 1 - \gamma$. This implies that the output production technology is linear in k_t, a result similar to the Ak model. Labor and capital markets are competitive; hence, the wage rate w_t and the rental rate of capital ρ_t at time t are given as

$$w_t = B(1-\gamma)k_t L_t^{-\gamma} \tag{3}$$

and

$$\rho_t = B\gamma L_t^{1-\gamma}. \tag{4}$$

Note that the number of firms in each period is equal to one (all old entrepreneurs) while the total labor in each period includes all young lenders (n), young entrepreneurs (1), and old consumers who receive their labor endowment ($x[\lambda p_b + (1-\lambda)p_g]$). Hence, $L_t = L = n + 1 + x[\lambda p_b + (1-\lambda)p_g]$. Given this, it is clear that $\rho_t = \rho_{t+1} = \rho$.

3.2 *Information Structure, Financial Intermediation, and Loan Contracts*

It has long been recognized that financial markets are characterized by a wide variety of imperfections and many of these imperfections are informational in nature. These informational imperfections cause frictions in transferring resources from lenders to borrowers and potentially give rise to credit rationing (McKinnon, 1973, Shaw, 1973). Moreover, financial intermediation (such as banks) plays an important role in easing these frictions (Diamond, 1984). To capture these features, we introduce two types of asymmetric information in this model economy. The first type is *ex ante*; i.e., the borrowers' risk type is private information and lenders have no ability to uncover it before they sign contracts with borrowers. As can be seen below, this gives a borrower an incentive to misrepresent her type in applying for a loan from a lender. To deter such behavior, a lender must ration credit to a fraction of borrowers (Bencivenga and Smith,

1993) under a separating equilibrium. The second type of asymmetric information is *ex post* such that, after a contract has been signed, the true outcome of entrepreneurs' capital projects as well as the true realization of the consumers' old-age labor endowment are private information. This gives a borrower an incentive to always declare a failure of capital investment or a zero realization of old-age labor endowment, independent of her actual state. To deter this behavior, it is well known that the optimal contract requires a lender to monitor (or to verify) a borrower's true state in the event of default. Verification, of course, is costly as a lender requires σ units of output per unit lent to verify the borrower's true outcome. Under this costly state verification (CSV) framework, if more than one lenders is needed to finance a borrower, then financial intermediation (or, in short, banks) will arise to economize the verification cost by performing the role of delegated monitoring (Diamond, 1984). It is assumed that any lender can costlessly establish a bank, which takes deposits from other lenders and makes loans to borrowers.

Beside these two types of asymmetric information, it has been recognized that the operation of financial intermediation is costly and such an intermediation cost creates a wedge between the loan rate and the deposit rate (Fry, 1995). Financial development, which enhances the efficiency of banking operations, is claimed to reduce the cost of intermediation and thereby this wedge. To capture this, we also assume that the operation of a bank is costly. Specifically, it costs a bank δ units of output per unit lent to the borrower to process a loan. As can be seen below, this so-called loan processing cost and the aforementioned verification cost constitute a wedge between the deposit and loan rates. A decrease in δ or σ represents a decrease in the cost of intermediation and hence can be interpreted as financial development. Note that financial development enhances not only the efficiency of loan making *ex ante*, but also the efficiency of verification *ex post*; hence, it is reasonable to assume that the loan processing cost and the verification cost are related. For this purpose, we assume that $\sigma = z\delta$, $z > 0$. Given this, a decrease in δ can be interpreted as a decrease in the intermediation cost and such a decrease is called as financial development in the analysis that follows.

4 The Equilibrium Loan Contracts

After receiving her wage income, a young lender at t can save her income for old-age consumption by adopting the L technology by herself. Alternatively, she can establish a bank (without incurring any cost) and utilize her own income as well as other lenders' income (as deposits) to finance entrepreneurs' capital projects or consumers' consumption in return for output in the next period. Free entry into banking implies that each bank earns zero economic profit from taking deposits and making loans and, as in Bencivenga and Smith (1993), competition among lenders implies that all gains from trade (between lenders and borrowers) accrue to borrowers. It is important to note that uncertainty about borrowers' outcome is idiosyncratic and there is no aggregate uncertainty. Hence, a bank can perfectly diversify loans and obtain a non-stochastic return on loans, which enables the bank to pay a fixed return to its depositors. As a consequence, the bank needs not be monitored by its depositors.

This paper follows Bencivenga and Smith (1993) by focusing on an equilibrium displaying self-selection of borrowers according to contracts accepted. The operation of the loans market is similar to that of Bencivenga and Smith (1993). Specifically, the bank, after receiving deposits at t, can announce a set of contracts to entrepreneurs (denoted as C^e_{it}, $i = g, b$) and a set of contracts to consumers (denoted as C^c_{it}, $i = g, b$). Each contract consists of a triple (R^j_{it}, q^j_{it}, π^j_{it}), $j = e, c$ and $i = b, g$, where R^j_{it} is the gross loan rate, q^j_{it} is the loan quantity offered, and π^j_{it} is the probability that the bank actually offer the contract. The separating equilibrium of the credit market is a Nash equilibrium such that $(R^j_{gt}, q^j_{gt}, \pi^j_{gt}) \neq (R^j_{bt}, q^j_{bt}, \pi^j_{bt})$ for $j = e$, c and no bank has incentive to offer an alternative contract at any date, taking other banks' offers as given. We now determine the equilibrium contracts for entrepreneurs and consumers, respectively.

4.1 *The Equilibrium Contracts for Entrepreneurs*

The expected utility of a type-i entrepreneur who reveals his true type by applying for C^e_{it}, $i = g$, b, is given by

$$p_i \pi^e_{it}[(q^e_{it} + w_t)Q\rho - q^e_{it}R^e_{it}] + (1 - \pi^e_{it})Q\varepsilon_i \rho w_t. \tag{5}$$

With probability π^e_{it}, the borrower receives q^e_{it}. Utilizing q^e_{it} and his own wage income w_t, the borrower can adopt the A technology to produce time-t+1 capital. Thus, $p_i \pi^e_{it}[(q^e_{it} + w_t)Q\rho - q^e_{it}R^e_{it}]$ represents the expected utility when the borrower receives the loan. With probability $1 - \pi^e_{it}$, the borrower's loan application is rejected. In this case, he must adpot the T technology by using his own wage income.

The terms of the separating equilibrium contracts can be derived by maximizing eq. (5) subject to the following constraints. First, competition among banks implies that C^e_{bt} and C^e_{gt} must separately earn each bank zero profit. Second, each type of entrepreneurs must prefer revealing their true type to cheating on their type when they apply for loans. Define Φ^e_R as the expected net rate of return from revealing true type for a type b borrower, which is equal to the expected net benefit of revealing true type for a type b entrepreneur divided by his own wage income w_t. Similarly, define Φ^e_P as the expected net rate of return for a type b entrepreneur from pretending as a type g entrepreneur, which is equal to the expected net benefit of a type b entrepreneur from pretending a type g entrepreneur divided by his own wage income w_t. Since an increase in the intermediation cost leads to a decrease in Φ^e_R, we define a $\overline{\delta}^e_R$ such that if $\delta = \overline{\delta}^e_R$, then $\Phi^e_R = 0$. We then obtain the terms of the equilibrium separating contracts as follows.[7]

Proposition 1. *Suppose that the intermediation cost is less than* $\overline{\delta}^e_R$ and $\varepsilon_g/p_g > \varepsilon_b/p_b$. *Then, the equilibrium separating contract for a type-b entrepreneur is characterized by* $C^e_{bt} = (R^e_{bt},\, q^e_{bt},\, \pi^e_{bt})$ *with* $R^e_{bt} = \frac{Q\varepsilon_b\rho(1+\delta)+(1-p_b)z\delta}{p_b}$, $q^e_{bt} = (\overline{m} - 1)w_t$, and $\pi^e_{bt} = 1$, *while the equilibrium separating contract for a type-g entrepreneur is characterized by* $C^e_{gt} = (R^e_{gt},\, q^e_{gt},\, \pi^e_{gt})$ *with* $R^e_{gt} = \frac{Q\varepsilon_b\rho(1+\delta)+(1-p_g)(z\delta-s_g)}{p_g}$, $q^e_{gt} = (\overline{m} - 1)w_t$, *and* $\pi^e_{gt} = \frac{\Phi^e_R}{\Phi^e_P} = \frac{p_b\overline{m}Q\rho-(\overline{m}-1)[Q\varepsilon_b\rho(1+\delta)+(1-p_b)z\delta]-Q\varepsilon_b\rho}{p_b\overline{m}Q\rho-(\overline{m}-1)\frac{p_b}{p_g}[Q\varepsilon_b\rho(1+\delta)+(1-p_g)(z\delta-s_g)]-Q\varepsilon_b\rho}$.

[7] The proofs of all results in this paper are available upon request.

To seethe results in Proposition 1, first note that if $\delta < \overline{\delta}_R^e$, type b entrepreneurs have incentive to borrow for adopting the A technology by revealing his true type. Since type g entrepreneurs have the better ability in adopting the A technology, the condition of $\delta < \overline{\delta}_R^e$ also ensures that type g entrepreneurs are willing to borrow (by revealing their true type). Second, each type of entrepreneurs at t must borrow $(\overline{m}-1)w_t$ because of indivisibility of technological adoption. Hence, $q_{bt}^e = q_{gt}^e = (\overline{m}-1)w_t$. Third, the optimal contract with the presence of CSV is a standard debt contract in which the bank receives a full interest payment in the borrowers' good state. In the borrowers' bad state, the bank obtains only the scrap value (if any) and verification takes place. Note that lending q_{it}^e to an entrepreneur cost the bank $(1+\delta)q_{it}^e$ units of output due the loan-processing cost. Thus, the zero-profit constraint for the bank can be expressed as $p_i q_{it}^e R_{it}^e - (1-p_i)(z\delta - s_i)q_{it}^e = (1+\delta)q_{it}^e Q\varepsilon_b \rho_{t+1}$, $i = g, b$, where the LHS of the equal sign is the expected return to the bank from making a loan and the RHS is the expected return to the bank when the bank alternatively adopts the T technology with $(1+\delta)q_{it}^e$ units of output. This leads to to R_{bt}^e and R_{gt}^e. Fourth, since $p_g > p_b$ and $s_g > s_b = 0$, it must be that $R_{bt}^e > R_{gt}^e$. Given that q_{bt}^e is equal to q_{gt}^e, this gives type b entrepreneurs the incentive to pretend as type b entrepreneurs and to enjoy a lower loan rate. By contrast, the condition of $\varepsilon_g/p_g > \varepsilon_b/p_b$ indicates that type g entrepreneurs have no incentive to pretend as type b entrepreneurs. Given that the terms of equilibrium contracts are obtained by maximizing entrepreneurs' expected utility, it is clear that the bank should not ration entrepreneurs who apply for C_{bt}^e, leading to $\pi_{bt}^e = 1$. Finally, type b entrepreneurs must have no incentive to pretend as type g ones under the separating equilibrium. As in Bencivenga and Smith (1993), this can be achieved by distorting the contract C_{gt}^e in a way such that the expected utility of a type b entrepreneur in revealing his true type is equal to that in pretending as a type g entrepreneur, which can be derived by setting the probability of obtaining the loan in C_{gt}^e (i.e. π_{gt}^e) equal to the ratio of the expected net rate of return from revealing true type for a type b entrepreneur (i.e. applying for C_{bt}^e) over the counterpart from pretending as a type g entrepreneur (i.e. applying for C_{gt}^e). This leads to $\pi_{gt}^e = \Phi_R^e/\Phi_P^e$.

Proposition 1 leads to the following results:

Corollary 1. *(a)Financial development, which is measured by a decrease in δ for $\delta \in [0, \overline{\delta}_R^e]$, leads to an increase in π_{gt}^e; (b) the marginal effect of financial development in increasing π_{gt}^e decreases along with financial development.*

To see the intutition, recall that π_{gt}^e is the relative rate of returns between truthful revealing and mimicking for a type b entrepreneur A decrease in δ reduces the costs of verification, which further reduce the loan rates in contracts C_{bt}^e and C_{gt}^e. Nevertheless, the fact that $p_g > p_b$ indicates that the loan rate in C_{bt}^e decreases more than that in C_{gt}^e, implying that the net rate of return from truthful revealing increases more than that of micmicking. This gives the type-b entrepreneurs less incentive to misrepresent their type (by applying for C_{gt}^e); hence, financial development eases the problem of asymmetric information. As the equilibrium contract is obtained by maximizing the borrowers' expected payoff, each bank can optimally increase the probability of obtaining loans (i.e., π_{gt}^e) in the contract C_{gt}^e; hence, the incidence of credit rationing decreases, resulting in the first result. Although a decrease in δ causes Φ_R^e to increase more than Φ_P^e, the gap between Φ_R^e and Φ_P^e declines along with financial development (i.e., along with the decrease in δ), leading to the second result of Corollary 1. In conclusion, asymmetric information leads to credit rationing and financial development, measured by a decrease in the intermediation cost, alleivates the problem of assymmetric information. However, the marginal effect of financial development in decreasing the incidence of credit rationing of type g entrepreneurs declines along with financial development.

4.2 *Equilibrium Contracts for Consumers*

The equilibrium separating contracts for consumers are very similar to those for entrepreneurs. The expected utility of a type-i consumer when she reveals her true type by applying for C_{it}^c is given by[8]

$$\pi_{it}^c[q_{it}^c + \mu p_i(xw_{t+1} - q_{it}^c R_{it}^c)] + (1 - \pi_{it}^c)\mu p_i x w_{t+1}, \ i = g, b. \tag{6}$$

[8]The superscript c refers to consumer borrowers.

The separating equilibrium contracts can be obtained by maximizing eq. (6) subject to the zero-profit constraint of the bank in lending to consumers as well as the incentive constraints that induce self selection. Define Φ_R^c as as the expected net rate of return of a type b consumer from truthful revealing and Φ_P^c as the expected net rate of return of a type b consumer from pretending as type g consumers. An increase in the intermediation cost reduces Φ_R^c; hence, we define a $\overline{\delta}_R^c$ such that if $\delta = \overline{\delta}_R^c$, then $\Phi_R^c = 0$. The separating equilibrium contracts can be derived as below:

Proposition 2. *Suppose that borrowers' discount factor μ is sufficiently small and the intermediation cost is less than $\overline{\delta}_R^c$. Then, the equilibrium separating contract for a type-b consumer is characterized by $C_{bt}^c = (R_{bt}^c,\ q_{bt}^c,\ \pi_{bt}^c)$ with $R_{bt}^c = \frac{Q\varepsilon_b\rho(1+\delta)+(1-p_b)z\delta}{p_b}$, $q_{bt}^c = \frac{xw_{t+1}}{R_{bt}^c}$, and $\pi_{bt}^c = 1$, while the equilibrium separating contract for a type-g consumer is given by $C_{gt}^c = (R_{gt}^c,\ q_{gt}^c,\ \pi_{gt}^c)$ with $R_{gt}^c = \frac{Q\varepsilon_b\rho(1+\delta)+(1-p_g)z\delta}{p_g}$, $q_{gt}^c = \frac{xw_{t+1}}{R_{gt}^c}$, and $\pi_{gt}^c = \frac{\Phi_R^c}{\Phi_P^c} = \frac{\frac{p_b}{Q\varepsilon_b\rho+(1-p_b)z\delta}-\mu p_b}{\frac{p_g}{Q\varepsilon_b\rho+(1-p_g)z\delta}-\mu p_b}$.*

The results in Proposition 2 are obtained in a similar fashion with that in Proposition 1. First, the assumption that μ is sufficiently small implies that each consumer intends to borrow all of her old-age wage income for young-age consumption, leading to $q_{bt}^c = q_{gt}^c = xw_{t+1}/R_{bt}^c$. Under the standard debt contract, the zero-profit constraint for the bank can be expressed as $p_i q_{it}^c R_{it}^c - (1-p_i)z\delta q_{it}^c = (1+\delta)q_{it}^c Q\varepsilon_b\rho$, $i = g,\ b$, which leads to R_{bt}^c and R_{gt}^c after using $q_{bt}^c = q_{gt}^c = xw_{t+1}/R_{bt}^c$. Third, since $p_g > p_b$, it is clear that $R_{bt}^c > R_{gt}^c$ and $q_{bt}^c < q_{gt}^c$. Both imply that type b consumers have incentive to pretend as type g consumers (by applying for C_{gt}^c) while type g consumers do not have incentive to pretend as type b ones. As a result, the bank should not ration credit to consumers who apply for C_{bt}^c, indicating that $\pi_{bt}^c = 1$. Finally, the separating equilibrium can be obtained by distorting C_{gt}^c such that type b consumers are indifferent between revealing their true type and pretending as type g consumers. This can be achieved by setting the probability of obtaiing the loan in C_{gt}^c (i.e. π_{gt}^c) equal to the ratio of the expected net rate of return of a type b consumer from truthful revealing Φ_R^c over the expected net rate of return of a type b consumer from pretending as a type g consumer Φ_P^c.

Proposition 2 leads to the following results.

Corollary 2. *(a) Financial development, measured by a decrease in δ, leads to an increase in π^c_{gt}; (b) the marginal effect of financial development in increasing π^c_{gt} decreases along with financial development.* ■

Intuitively, a decrease in δ causes Φ^c_R to increase more than Φ^c_P. This gives type b consumers less incentive in pretending as type g consumers: hence, financial development alleviates the problem of asymmetric information and reduces the incidence of credit rationing. Moreover, though a decrease in δ cause both Φ^c_R and Φ^c_P to increase, the gap between Φ^c_R and Φ^c_P declines along with the decrease in δ. This implies that the marginal effect of a decrease in δ in reducing the incidence of credit rationing (of type g consumers) declines along with the decrease in δ.

4.3 Discussion

Some aspects of equilibrium credit rationing derived in this paper merit furhter comments. This paper follows Bencivenga and Smith (1993) by mainly focusing on a separating equilibrium that displays self-selection of borrowers according to contracts accepted. Theoretically speaking, it is also possible that pooling equilibrium may exist in this framework. Nevertheless, it is readily verified that if the fraction of type b borrowers, λ, is sufficiently large, then pooling equilibrium does not exist.[9] Hence, our analysis holds under the assumption that λ is sufficiently large. We intend to focus on the separating equilibeium, because it yields equilibrium credit rationing that has received empirial support (see below for references).[10] Note also that the derived separating equilibrium contracts have a feature of adverse selection, as borrowers who accept a contract with a higher loan rate (i.e. type b borrowers) have a higher probability of default than those borrowers who accept a contract with a lower loan rate (i.e. type g borrowers). Empirically, some works have found evidence in support of this adverse selection with borrowers self-selecting into contracts with verying loan rates. For example, Edelberg (2004) investigates U.S. consumer

[9] See Appendix 3 for the results.

[10] As presented in Appendix 1, credit rationing disappears under pooling equilibrium in this framework, Note also that credit rationing may disappear under the separating equilibrium if we allow lenders to verify borrowers' types. This is modeled by Bose and Cothren (1996) in the screening regime.

loan markets and finds robust evidence of adverse selection with borrowers self selection into contracts in which high risk borrowers pay a higher loan rate and low risk ones pay a lower loan rate. Ausubel (1999) uses market experiments conducted by a large American credit card lender, and find that solicitations offering a higher interest rate yield customer pools with worse observable credit risk characteristics than solicitations offering a lower interest rate.

Moreover, type g entrepreneurs are more likely to be credit rationed in this paper than type b ones. Using data from SMEs in Belgian for the period 1993-2001, Steijvers (2004) finds evidence that credit rationed firms, who seek long term bank credit, have a higher added value and retrun on assets than unconstrainted firms.[11] As type g entrepreneurs possess a higher ability (and hence a higher return) in capital investment, this finding implies that equilibrium credit rationing derived in this paper is consistent with reality.

Finally, it is known that credit ratioing may disappear with more sophisticated contracts. Bolton and Dewatripont (2005, p. 57-62), for example, illustrate that if the bank can offers contracts that differs both in terms of repayment and in terms of probability of obtaining the loan, then credit rationing disappears when the expected rate of returns for type g and b borrowers (i.e., $p_i Q\rho$) are equal. In this paper, the scenario illustrated by Bolton and Dewatripont does not hold as the expected rate of return for type g borrowers is higher then that for type b borrowers. We allow credit rationing in this paper because many empirical works, e.g., Jappelli (1990), Perez (1998), Banerjee and Duflo (2002), Banerjee et al. (2003), and Baker et al. (2003), have confirmed the existence of credit rationing. Moreover, the assumption that both types of borrowers have the same expected rate of return may be too strong to be the case in reality.

5 Financial development and economic growth

Once we obtain the equilibrium contracts for entrepreneurs and consumers, the correlation between financial development and economic growth can be examined. To this purpose, we first

[11] For those firms who seek short term bank credit, Steijvers (2004) finds that crdit rationed firms have a low return on assets and added value.

derive capital investment and hence the rate of economic growth according to the equilibrium contracts we obtained in previous section. We then characterize how financial development affects economic growth through its effects on investment and consumption loans, respectively. In particular, we provide some numerical examples to show how this model can yield the nonlinear correlation between financial development and economic growth.

5.1 Equilibrium contracts and economic growth

From the equilibrium contracts, we see that the total amount of resources used to finance consumers' consumption at t is given as $[\lambda\frac{xw_{t+1}}{R^c_{bt}} + (1-\lambda)\pi^c_{gt}\frac{xw_{t+1}}{R^c_{gt}}](1+\delta)$, while the total amount used to finance entrepreneurs' investment is given as $[\lambda + (1-\lambda)\pi^c_{gt}](\overline{m}-1)(1+\delta)w_t$.

Denoting k_{t+1} as the per firm capital stock at t+1, we have

$$\begin{aligned} k_{t+1} &= \{nw_t - [\lambda + (1-\lambda)\pi^e_{gt}](\overline{m}-1)(1+\delta)w_t - [\lambda\frac{xw_{t+1}}{R^c_{bt}} + (1-\lambda)\pi^c_{gt}\frac{xw_{t+1}}{R^c_{gt}}](1+\delta)\}Q\varepsilon_b \\ &\quad +\{\lambda p_b Q\overline{m}w_t + (1-\lambda)[p_g\pi^e_{gt}\overline{m} + (1-\pi^e_{gt})\varepsilon_g]\}Qw_t, \end{aligned}$$

where the first part of the capital is produced by banks who adopt the T technology and the second part of capital is produced by the entrepreneurs who adopt the A and T technologies.[12] Note that consumption loans adversely affect capital production as they reduce the total resources available for converting capital by the bank. By substituting the equilibrium contracts as well as eq. (3) into the above equation, the rate of economic growth between t and t+1 (denoted as G) is given as

$$1 + G = \frac{k_{t+1}}{k_t} = \frac{E^e}{E^c}QB(1-\gamma)L^{-\gamma}, \tag{23}$$

where

$$E^e \equiv n\varepsilon_b + \lambda[p_b\overline{m} - \varepsilon_b(\overline{m}-1)(1+\delta)] + (1-\lambda)\pi^e_{gt}[p_g\overline{m} - \varepsilon_g - \varepsilon_b(\overline{m}-1)(1+\delta)] + (1-\lambda)\varepsilon_g \tag{24}$$

[12] Note that all type-b entrepreneurs as well as type-g entrepreneurs who receive loans adopt the A technology. Type-g entrepreneurs who are credit-rationed must adopt the T technology by using their own wage as input.

and

$$E^c \equiv 1 + [\lambda \frac{p_b x}{Q\varepsilon_b \rho + (1-p_b) z \frac{\delta}{(1+\delta)}} + (1-\lambda)\pi^c_{gt} \frac{p_g x}{Q\varepsilon_b \rho + (1-p_g) z \frac{\delta}{(1+\delta)}}] Q\varepsilon_b B(1-\gamma)L^{-\gamma}. \quad (25)$$

Note that E^e represents the growth component originated from intermediated productive/investment loans while E^c refers to the counterpart from intermediated non-productive/consumption loans.

5.2 Effects of financial development on Investment and consumption loans

Financial development, measured by a decrease in δ, has two effects on the growth component of investment loans E^e. The first one is a quality effect, meaning that the quality of investment loans increases. This effect is derived because a decrease in δ eases the problem of asymmetric information and hence raises the probability of obtaining loans (i.e. π^e_{gt}) for more efficient entrepreneurs (i.e. type g entrepreneurs) whose projects have a high probability of success. The second one is a quantity effect of investment loans, as a decrease in δ reduces the amount of resources absorbed in financing entrepreneurs' investment (due to the loan-processing cost), which increases the total quantity of resources available for the bank to produce capital. This quantity effect from investment loans is represented by $p_b\overline{m} - \varepsilon_b(\overline{m}-1)(1+\delta)$ and $p_g\overline{m} - \varepsilon_g - \varepsilon_b(\overline{m}-1)(1+\delta)$ in eq. (24) and, for future reference, is denoted as QI. Similarly, a change in δ has two effects on the growth component of consumption loans E^c. The first one is a quality effect, as a decrease in δ raises the probability of obtaining loans for type g consumers (with a lower probability of default) and hence increases the quality of total outstanding consumption loans. The second effect is a quantity effect, as a decrease in δ reduces the loan rates R^c_{it} and hence increases the amount a consumer intends to borrow. This will reduce the total quantity of resources available for the bank to produce capital. This quantity effect is represented by $p_i x/[Q\varepsilon_b\rho + (1-p_i)z\frac{\delta}{1+\delta}]$ in eq. (25) and is denoted by QC for future reference. By interpreting a decrease in the intermediation cost δ as financial development, financial development riases π^e_{gt}

and π_{gt}^c (Corollary 1 and Corollary 2). On the other hand, financial development raises both QI and QC. Together with these results, eqs. (24) and (25) indicate that financial development raises both E^e and E^c (i.e., $\partial E^e/\partial\delta < 0$ and $\partial E^c/\partial\delta < 0$).

To examine the relationship between financial development and economic growth, from eq. (23) we calculate

$$\frac{\partial \ln(1+G)}{\partial\delta} = \frac{\partial}{\partial\delta}\ln E^e - \frac{\partial}{\partial\delta}\ln E^c. \tag{26}$$

Since $\partial E^e/\partial\delta < 0$ and $\partial E^c/\partial\delta < 0$, it is clear that $\partial \ln E^e/\partial\delta < 0$ and $\partial \ln E^c/\partial\delta < 0$. Given this, $\partial \ln(1+G)/\partial\delta < (resp. >)0$ if $\left|\frac{\partial}{\partial\delta}\ln E^e\right| > (resp. <)\left|\frac{\partial}{\partial\delta}\ln E^c\right|$, where $|\partial \ln E^e/\partial\delta|$ represents the marginal growth effect of financial development originated from investment loans and $|\partial \ln E^c/\partial\delta|$ corresponds to the marginal growth effect of financial development originated from consumption loans. Formally, we have the following result:

Propostion 3. *Financial development, measured by a decrease in δ, leads to an increase (resp. a decrease) in economic growth if $\left|\frac{\partial}{\partial\delta}\ln E^e\right| > (resp. <)\left|\frac{\partial}{\partial\delta}\ln E^c\right|$.*

Note that $\left|\frac{\partial}{\partial\delta}\ln E^e\right| = -\frac{\partial E^e}{\partial\delta}/E^e = \left|\frac{\partial E^e}{\partial\delta}\right|/E^e$ and $\left|\frac{\partial}{\partial\delta}\ln E^c\right| = -\frac{\partial E^c}{\partial\delta}/E^c = \left|\frac{\partial E^c}{\partial\delta}\right|/E^c$. We characterize $|\partial \ln E^e/\partial\delta|$ and $|\partial \ln E^c/\partial\delta|$ as below.[13]

Proposition 4. *(a) The marginal growth effect of financial development originated from investment loans (i.e., $\left|\frac{\partial}{\partial\delta}\ln E^e\right|$) is increasing in δ for $\delta \in [0, \overline{\delta}_R^e]$; (b) the marginal growth effect of financial development from consumption loans (i.e., $\left|\frac{\partial}{\partial\delta}\ln E^c\right|$) is first decreasing in δ and then increasing in δ for $\delta \in [0, \overline{\delta}_R^c]$.*

To grasp the intuition of Proposition 4, recall that a decrease in δ raises π_{gt}^e and QI, both of which lead to an increase in E^e (hence, $\partial E^e/\partial\delta < 0$ and $|\partial E^e/\partial\delta| > 0$). Figure 1.a depicts the correlation between δ and E^e for $\delta \in [0, \overline{\delta}_R^e$ under a numerical example presented below. From the result (b) of Corollary 1, the marginal effect of a decrease in δ in raising π_{gt}^e (i.e. the value of $\partial\pi_{gt}^e/\partial\delta$) declines along with a decrease in δ for $\delta \in [0, \overline{\delta}_R^e]$ (because $\partial^2\pi_{gt}^e/\partial\delta^2 < 0$). However, due to the indivisibility of capital investment, the marginal effect of a decrease in δ in reducing

[13] Proposition 3 holds under some parameter conditions, which is stated in Appendix 4.

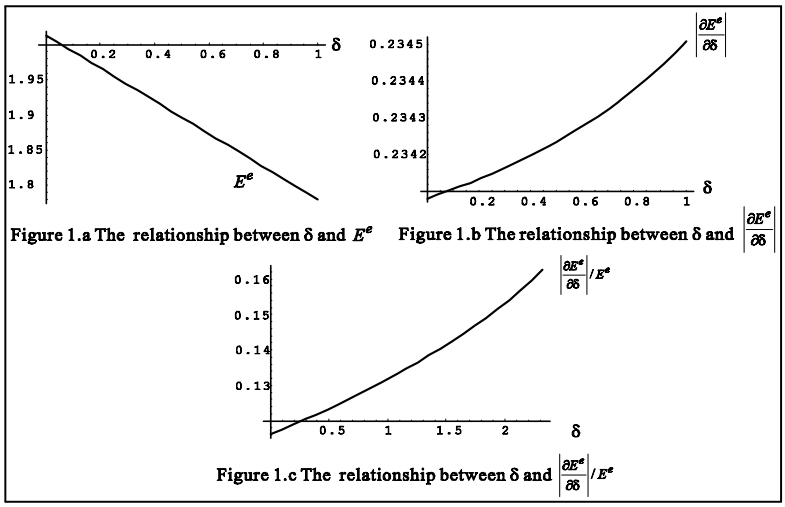

Figure 1: Financial development and its effects on E^e

QI is constant (which is equal to $\varepsilon_b(\overline{m}-1)$). Consequently, the marginal effect of financial development in raising E^e (which is the value of $|\partial E^e/\partial\delta|$) is decreasing in financial development (i.e., increasing in δ from 0 to the upper bound $\overline{\delta}_R^e$). Figure 1.b depicts the correlation between δ and $|\partial E^e/\partial\delta|$ for $\delta \in [0, \overline{\delta}_R^e]$. The marginal effect of financial development on economic growth that is originated from investment loans (i.e., $\left|\frac{\partial}{\partial\delta}\ln E^e\right|$) is equal to $\left|\frac{\partial E^e}{\partial\delta}\right|/E^e$, which is depicted in Figure 1.c. As is depicted, financial development, measured by a decrease in δ from $\overline{\delta}_R^e$ to 0, leads to a decrease in $\left|\frac{\partial}{\partial\delta}\ln E^e\right|$.

A decrease in δ raises π_{gt}^c and QC, which furhter leads to an increase in the growth component of intermediated consumption loans E^c. Figure 2.a depicts the correlation between δ and E^c for $\delta \in [0, \overline{\delta}_R^c]$ under a numerical example presented below. According to the result (b) in Corollary 2, the marginal impact of a decrease in δ in raising π_{gt}^c (i.e. the value of $\partial\pi_{gt}^c/\partial\delta$) declines along with a decrease in δ from its upper bound $\overline{\delta}_R^c$ to 0 (due to the fact that $\partial^2\pi_{gt}^c/\partial\delta^2 < 0$). On the other hand, a decrease in δ raises QC and the marginal impact of this effect (i.e. the value of $\partial QC/\partial\delta$) increases along with a decrease in δ for $\delta \in [0, \overline{\delta}_R^c]$, because $\partial^2 QC/\partial\delta^2 > 0$. Combining these two results, the marginal impact of financial development in raising E^c (i.e. the value of $|\partial E^c/\partial\delta|$) may increase or decrease along with a decrease in δ from the upper bound $\overline{\delta}_R^c$ to 0. Nevertheless, $\partial^2\pi_{gt}^c/\partial\delta^2 < 0$ implies that the marginal effect of a decrease in δ in raising π_{gt}^c is

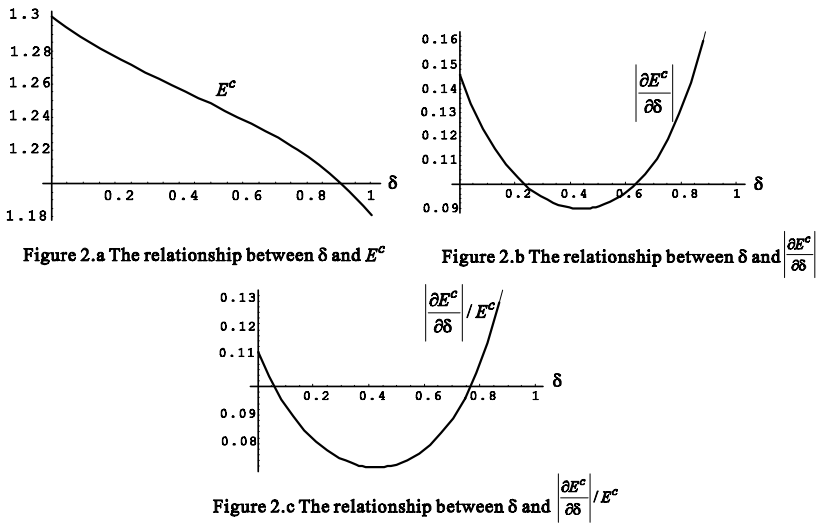

Figure 2: Financial development and its effects on E^c

relatively large for large levels of δ, while $\partial^2 QC/\partial\delta^2 > 0$ imply that the marginal effect of a decrease in δ in rasing QC is relatively large for small levels of δ. As a result, the marginal effect of a decrease in δ in raising QC dominates (*resp.* is dominated by) that in raising π_t^c for relatvely small (*resp.* large) levels of δ, implying that the marginal impact of a decrease in δ in raiseing E^c (i.e. the value of $|\partial E^c/\partial\delta|$) is first decreasing in δ and then increasing in δ, implying that the locus of $|\partial E^c/\partial\delta|$ is U-shaped. Figure 2.b depicts the correlation between $|\partial E^c/\partial\delta|$ and δ for $\delta \in [0, \overline{\delta}_R^c]$. The marginal effect of financial development on economic growth that is originated from consumption (i.e. $\left|\frac{\partial}{\partial\delta}\ln E^c\right|$) is equal to $|\partial E^c/\partial\delta|/E^c$. As $|\partial E^c/\partial\delta|$ is first decreasing and then increasing in δ while E^c is always decreasing in δ, the locus of $|\partial E^c/\partial\delta|/E^c$ is also U-shaped, as is depicted in Figure 2.c.

It is instructive to compare the loci of $\left|\frac{\partial}{\partial\delta}\ln E^e\right|$ (Figure 1.c) and $|\partial E^c/\partial\delta|/E^c$ (Figure 2.c). As is shown, the locus of $\left|\frac{\partial}{\partial\delta}\ln E^e\right|$ is decreasing in financial development (or increasing in δ), while the locus of $|\partial E^c/\partial\delta|/E^c$ is U-shaped. From the above analysis, the key element that generates this difference is that the marginal effect of financial development in raising QI is constant (due to the indivisiblity of capital investment), but such a marginal effect in raising QC is increasing in financial development (i.e. decreasing in δ). As can be seen in below, this

difference plays a key role in yielding a result consistent with Rioja and Valev (2004).

It is also instructive to inspect the finance-growth relationship by considering only investment loans or consumption loans, resepctively. If we consider only investment loans along (by assuming that E^c is independent of δ), then financial development unambiguously facilitates economic growth. This is implied by Figure 1.a, as financial development raises E^e and, according to eq. (26), economc growth. This has been confirmed by many empirical works (e.g., King and Levine, 1993). Moreover, the marginal impact of financial development on economic growth declines along with financial development, as implied by Figure 1.b. Using CREDIT as an indicator of financial development, De Gregorior and Guidotti (1995) find that the effect of financial development on economic growth is more significant in low- and middle-income countries than high-income countries. As financial sector is more developed in high-income countries than in low- and middle-income countries, their result is consistent with Figure 1.b. While considering only investment loans may yield results consistent with De Gregorior and Guidotti (1995), it cannot yield results consistent with Rioja and Valev (2004) and Shen and Lee (2006). It should be noted that CREDIT contains loans for consumption and investment. As can be seen below, once we integreate consumption loans with investment loans, the result of De Gregorior and Guidotti (1995) can be replicated. Thus, integrating investment and consumption loans has the advantage in explaining the nonlinear relationship between financial development and economic growth.

If we consider only consumption loans along (by assuming E^e is independent of δ), then financial development that faciliates consumption reduces total resources available for capital investment, whcih impedes economic growth.[14] Jappelli and Pagano (1994) estimate the effect of maxmiun loan-to-value (LTV) of mortgage loans on economic growth. They find that a higher LTV leads to a lower economic growth. This is consistent with Figure 2.a, as financial

[14] A caveat shoule be mentioned. While financial development that facilitates consumption loans may hurt economic growth, it is benefical to consumers' utility as it raises the total amount borrowed by consumers. Becasue this paper focuses on explaining the relationship between financial development and economic growth, we do not examine the utility issues. For a paper that discusses related issues, please see Jappelli and Pagano (1994).

development riases E^c and hence adversely affects economic growth. The marginal impact of this effect depends on two forces: the marginal impacts of financial development on π_t^c (the quality of consumption loans) and QC (the quantity). Unfortunately, there is no empirical work that distinguishes the quality of consumption loans from its quantity. Though no evidence on the marginal effect of financial development on E^c is available, the quality and quantity effects of consumption loans do exist. To see this, note that it is asserted that financial development reduces the spead between the deposit and loan rates (Mry, 1995).[15] Moreover, as is discussed in the last section, Edelberg (2004) finds evidence from U.S. consumer loan markets that borrowers self selection into contracts in which high risk borrowers pay a higher loan rate and low risk ones pay a lower loan rate. Combining these two results, financial development that reduces the loan rate must be associated with a decrease in the risk level of consumption loans. Finally, the quantity effect of cosumption loans also receives some empirical support. Alessie, Hochguertel, and Weber (2005) find evidence from Italian micro data that the demand of consumer credit is interest rate elastic, with a higher interest rate assoicated with a lower loan quantity demanded (Table 5). This may lend support to the existence of the quantity effect of consumption loans in this paper, as financial development reduces the loan rate in this paper and leads to an increase in the loan quantity.

5.3 Financial development and economic growth: nonlinearity

Once we characterize the relative magnitudes of $\left|\frac{\partial}{\partial\delta}\ln E^e\right|$ and $\left|\frac{\partial}{\partial\delta}\ln E^c\right|$, we can examine the nonlinear relationship between financial development and economic growth. To better illustrate our analysis, we provide four numerical examples that yield the nonlinear finance-growth relationships consistent with recent empirical studies. Consider the first example where $n = 6$, $\lambda = 0.7$, $p_b = 0.5$, $p_g = 0.6$, $\varepsilon_u = 0.18$, $\varepsilon_g = 0.4$, $s_g = 0.2$, $Q = 2.3$, $A = 1.05$, $\alpha = 0.36$, $x = 3$, $z = 0.5$, $\overline{m} = 2.2$, and $\mu = 0.67$. In this example, $\overline{\delta}_R^c$ is equal to 1.0 while $\overline{\delta}_R^e$ is equal to 2.3. For both types of loans to appear, we should condier the intermediation cost δ that lies between 0 and

[15] The deposit rate is equal to the rate of return from the T technology in this paper.

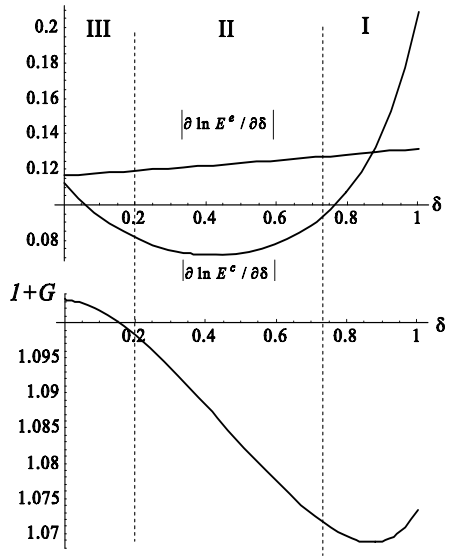

Figure 3: Financial development, $\left|\frac{\partial \ln E^e}{\partial \delta}\right|$, $\left|\frac{\partial \ln E^c}{\partial \delta}\right|$, and economic growth: the first example

1.0. The loci of $\left|\frac{\partial \ln E^e}{\partial \delta}\right|$ and $\left|\frac{\partial \ln E^c}{\partial \delta}\right|$ as functions of δ under this economy for $\delta \leq 1.0$ is depicted in Figure 1.c and 2.c, which are replicated in the upper half of Figure 3. The corresponding rate of economic growth is depicted in the lower half of Figure 3. Recall that financial development increases (*resp.* decreases) economic growth if $\left|\frac{\partial \ln E^e}{\partial \delta}\right| > (resp. <) \left|\frac{\partial \ln E^c}{\partial \delta}\right|$. As shown, the effect of financial development on economic growth is uncertain for high levels of δ (i.e., in regime I of Figure 3). For middle levels of δ (i.e., for δ in regime II), $\left|\frac{\partial \ln E^e}{\partial \delta}\right|$ overwhelmingly denominates $\left|\frac{\partial \ln E^c}{\partial \delta}\right|$; thus, financial development significantly promotes growth. For low levels of δ (i.e., for δ in regime III), $\left|\frac{\partial \ln E^e}{\partial \delta}\right|$ still dominates $\left|\frac{\partial \ln E^c}{\partial \delta}\right|$ so that financial development has a positive effect on growth. Nevertheless, since $\left|\frac{\partial \ln E^c}{\partial \delta}\right|$ is increasing in financial development (i.e., $\left|\frac{\partial \ln E^c}{\partial \delta}\right|$ is decreasingg in δ) in regime III, the positive effect of financial development on growth in regime III is less significant than that in regime II. Obviously, this example replicates the empirical result found by Rioja and Valev (2004).

In the second example, $p_b = 0.42$, $\varepsilon_u = 0.15$, $\varepsilon_g = 0.38$, $A = 0.88$, $\alpha = 0.25$, and $\mu = 0.65$. All other exogenous variables are identical to the first example. In this example, $\left|\frac{\partial \ln E^e}{\partial \delta}\right|$ and $\left|\frac{\partial \ln E^c}{\partial \delta}\right|$ are depicted in the upper half of Figure 4 while the correlation between economic growth and δ is depicted in the lower half of Figure 4. As shown, $\left|\frac{\partial \ln E^e}{\partial \delta}\right| > (<) \left|\frac{\partial \ln E^c}{\partial \delta}\right|$ for $\delta > (<) 0.268$. Thus,

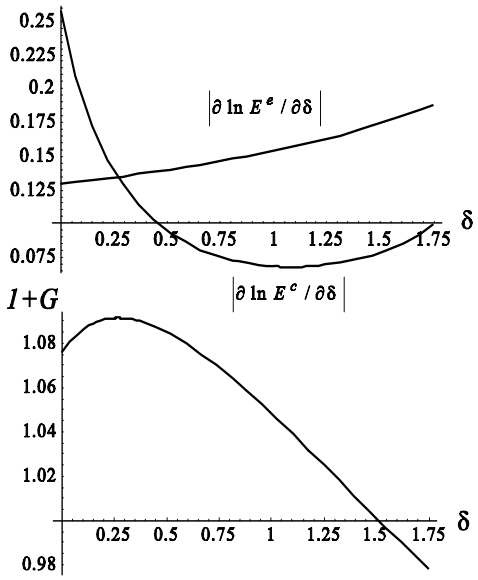

Figure 4: Financial development, $\left|\frac{\partial \ln E^e}{\partial \delta}\right|$, $\left|\frac{\partial \ln E^c}{\partial \delta}\right|$, and economic growth: the second example

the relationship between financial development and economic growth is an inverse-U shape. Financial development first promotes growth for low levels of financial development (i.e., for $\delta > 0.268$). For high levels of financial development (i.e., for $\delta < 0.268$), financial development reduces economic growth. This example is consistent with Shen and Lee (2006).

In the third example, $\varepsilon_u = 0.25$, $A = 0.95$, $\alpha = 0.4$, and all other variables are identical to the first example. In this example, $\left|\frac{\partial \ln E^e}{\partial \delta}\right|$ and $\left|\frac{\partial \ln E^c}{\partial \delta}\right|$ are depicted in the upper half of Figure 5 while the correlation between economic growth and δ is depicted in the lower half of Figure 5. Because financial markets are more developed in high income countries than in low income countries, regime I (defined in Figure 5) corresponds to low income countries, while regime II refers to high income countries. Apparently, financial development has an ambiguous effect on economic growth for low income countries, but has a significantly positive effect on growth for high income countries. As a result, this example accords well with the empirical result by Deidda and Fattouh (2002).

Finally, $p_b = 0.42$, $\varepsilon_g = 0.38$, $\varepsilon_u = 0.15$, $A = 1.2$, $\alpha = 0.38$, $\mu = 0.65$ in the fourth example and all other variables are the same as in the first example. Figure 6 is the corresponding

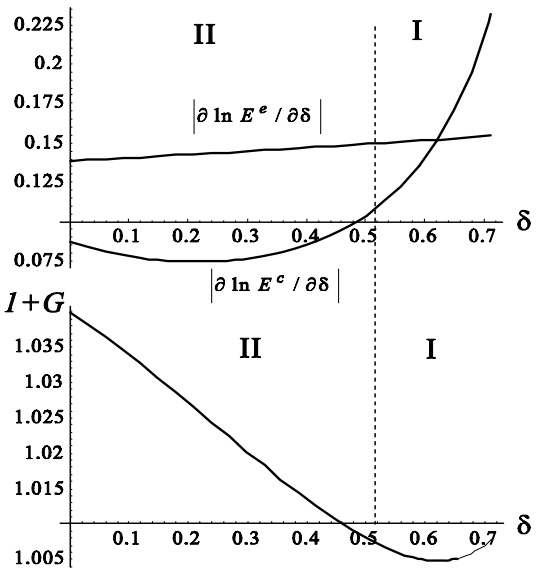

Figure 5: Financial development, $\left|\frac{\partial \ln E^c}{\partial \delta}\right|$, $\left|\frac{\partial \ln E^e}{\partial \delta}\right|$, and economic growth: the third example

figure for this example. As shown, financial development always promotes economic growth. Nevertheless, the marginal effect of financial development on economic growth is bigger in regime I (defined in Figure 6) than in regime II. As regime I corresponds to low and middle income countries, while regime II refers to high income countries, the fourth example indicates that the effect of financial development on economic growth is more significant in low and middle income countries than in high income countries. This result captures the empirical findings of De Gregorios and Guidotti (1995).

6 Conclusion

Recent empirical studies have discovered various nonlinear relationships between financial development and economic growth. Theoretical models in the recent literature, however, fail to account for all nonlinear finance-growth relationships found by recent empirical studies. To account for this nonlinear relationship, this paper develops a model that incorporates non-productive consumption loans with productive investment loans in a standard model of asymmetric information.

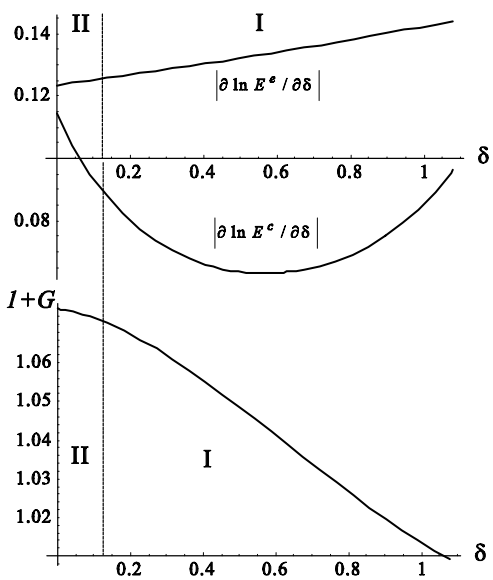

Figure 6: Financial development, $\left|\frac{\partial \ln E^e}{\partial \delta}\right|$, $\left|\frac{\partial \ln E^c}{\partial \delta}\right|$, and economic growth: the fourth example

In this model, financial development facilitates both investment loans and consumption loans. While facilitating investment loans benefits economic growth, facilitating consumption loans impedes economic growth. As a result, the effect of financial development on economic growth depends on the relative magnitudes of these two distinct channels. It is found that the initial level of financial development (i.e. the initial level of intermediation cost) plays a key role in determining the relative magnitudes of these two channels, yielding nonliear relationships between financial development and economic growth. In particular, we show that integrating consumption loans with investment loans can replicate nonliear relaitonships between financial development and economic growth found by recent empirical works. This highlights the importance of this paper.

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Second Year Project

Public Capital, Credit Subsidy, and Economic Growth

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Abstract

This paper examines the optimal government policies on tax-financed public investment and credit subsidies with the presence of asymmetric information. We find an optimal subsidy ratio and an optimal tax rate that maximize economic growth. In particular, both the optimal subsidy ratio and the optimal tax rate are positively related with the severity of asymmetric information. The implications of these results, though contradict the existing theoretical literature, are consistent with some empirical observations.

Keywords: Public Capital; Taxation; Endogenous Growth; Loan Subsidy; Asymmetric Information
JEL Classification: D82; H21; O41

1. Introduction

The importance of government taxation and spending policies in determining an economy's productivity and growth has been highlighted by the theory of endogenous growth. Typically, government taxation creates two opposite effects on productivity and hence economic growth. First, it absorbs private resources, which discourages private agents' incentive in capital investment and thus leads to an adverse effect on output production as well as growth. Second, it raises resources for government spending on public capital investment and hence increases public capital, which enhances the productivity of output production and thereby is beneficial to growth. The optimal income tax rate, or the optimal size of government spending under a balanced budget, is obtained by balancing these two opposite effects. In a world without any friction in market transactions, each unit of public capital investment requires the government to absorb just a unit of private resources. Thus, the optimal tax rate that maximizes growth in a frictionless world is equal to the output elasticity of public capital. Examples along this line of research include Barro (1990), Barro and Sala-i-Martin (1992), Futagami et al. (1993), and Glomm and Ravikumar (1997).[1]

There are frictions in market transactions, however. Due to this, a few researchers have recently incorporated frictions in studying the optimal taxation policies. Chen (2003), for example, incorporates tax evasion into Barro's (1990) model. As an increase in the tax rate, other things being equal, gives the firm/household more incentive to evade taxes, Chen (2003) shows that each unit of public capital investment requires the government to tax more than one unit of private output, implying that the optimal tax rate with the presence of tax evasion is greater than the output elasticity of public capital. Marrero and Novales (2005), on the other hand, include a wasteful component of public spending into Barro's (1990) model and find that the optimal tax rate is less than the output elasticity of public capital.

In a more interesting paper, Ho and Wang (2005) consider an

[1] While Barro (1990) treats the current flow of public capital as the source of contribution to output production, Futagami et al. (1993) view the stock of public capital as the contributing source. However, both studies find that the optimal tax rate under the balance growth path is equal to the output elasticity of public capital.

overlapping-generations economy, in which borrowers search for loans from lenders to implement their investment projects. Borrowers are classified as either high risk or low risk according to their default probability. Since borrowers' risk type is private information, lenders, as in Bose and Cothren (1996), must screen a fraction of borrowers with a positive probability to induce self-selection under the separating equilibrium. Incorporating the above asymmetric information problem with government policy of taxation and spending, Ho and Wang (2005) show that income taxation gives high risk borrowers more incentive to pretends as low-risk ones and hence exacerbates the problems of asymmetric information. In response to this, the equilibrium screening probability must increase. As screening is costly, this implies that income taxation creates a greater extent of distortion than it would be in a perfect market. As a result, the optimal tax rate, after taking this additional distortion into account, should be less than the output elasticity of public capital. Moreover, when the screening cost increases, the distortion induced by taxation becomes more severe, implying that the optimal tax rate should decreases. Thus, the optimal tax rate is negatively related with the severity of asymmetric information.

While Ho and Wang's (2005) analysis is quite insightful, they confine their analysis to the partial equilibrium and hence totally ignore the potential effects from general equilibrium. Moreover, they also ignore a well established fact that market imperfections create a role for the government to play. Specifically, screening is costly, so that a borrower, when screened, will receive a loan with a quantity less than the one when the borrower is not screened. Because borrowers are more efficient than lenders in private capital investment, this indicates that the lending volume with the presence of asymmetric information is not efficient in the sense that it is less than the one within a perfect market. This is the rationale for government to design various forms of credit subsidies intended to increase the efficiency of capital investment.[2] As a result, government credit subsidies are pervasive worldwide.[3]

[2] The effects of government credit subsidies have been extensively analyzed by Smith and Stutzer (1989), Gale (1990, 1991), Bencivenga and Smith (1993), Williamson (1994), and Li (1998, 2002), among others.

[3] This is true even in developed countries. For example, in the United States the federal credit programs (in the forms of loan guarantee, direct lending, and interest rate subsidies) account for about

In a partial equilibrium framework, Ho and Wang (2005) assume that borrowers' capital investment project is linear in terms of capital production. Due to this assumption, they further assume that each borrower can only contract with a lender; thus, the maximal amount a borrower can obtain is equal to the lender's after-tax labor income. Assuming that lenders face an exogenously given opportunity cost on their after-tax labor income, they show that an increase in the tax rate will give high-risk borrowers more incentives to pretend as low-risk ones and hence exacerbate the problem of asymmetric information. As a consequence, taxation leads to an additional distortion to the economy and hence the optimal tax rate should be less than the output elasticity of public capital. In this paper, we first relax the assumption of one-to-one match between lenders and borrowers by assuming that there exists an optimal scale to each borrower's capital investment and the rate of return for lenders' after-tax labor income is endogenously determined by the equilibrium of the credit market. By so doing, we find that an increase in the tax rate affects high- and low-risk borrowers at the same scale and hence does not exacerbate the problem of asymmetric information.

As stated, credit subsidies are commonly encountered in the real world. Since the government also relies on taxation to finance its credit subsidies, the optimal tax rate and its correlation with the severity of asymmetric information must be affected by government credit subsidies. This appears to be an untouched topic in the existing literature. We then further integrate our model with the case that the government subsidizes a fraction of screening costs to each lender.[4] By so doing, we

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one third of total credit market debt over the 1980-1987 period (Gale, 1990). Similarly, the European Community budget for credit programs was as large as 12.7 billion Euros per year between 1995 and 1999 (Patacchini and Rapisarda, 2003). Note that, as is pointed out by Ho and Wang (2005), some studies, such as Shi (1996) and Azariadis and Smith (1999), disagree with the popular view that asymmetric information is harmful to capital investment and economic growth. Similarly, some researchers, such as De Meza and Webb (1987) and De Meza (2002), argue that asymmetric information may lead to overlending and hence government credit subsidies are not desirable. It should be noted that this view does not contribute to explain why government credit subsidies are so pervasive worldwide.

[4] Indeed, the problem of asymmetric information results in the probability of costly screening in credit market equilibrium. If the screening cost is equal to zero, then asymmetric information will not cause any frictions on capital investment. Thus, to ease the problem of asymmetric information, it is

obtain conclusions that are in sharp contrast with Ho and Wang (2005). First, if there is no government subsidy, then the optimal tax rate is still equal to the output elasticity of public capital, a result that is in sharp contrast with Ho and Wang (2005) but is consistent with Barro (1990). The reason for this is because, after extending the partial equilibrium to the general equilibrium, taxation itself will not exacerbate the problem of asymmetric information. Second, an increase in the severity of asymmetric information (measured by an increase in the screening cost) leads to an increase in the optimal tax rate. This happens because, on the one hand, it is optimal for the government to increase its credit subsidies when the screening cost increases and, on the other hand, the government relies on taxation to finance its subsidy. While these two results differ from Ho and Wang (2005), their implications, as reviewed below, are consistent with some empirical observations.

As developed countries usually possess a more efficient financial sector than developing ones, our result implies that developing countries should provide more credit subsidies than developed ones. Moreover, in terms of maximizing economic growth, the optimal tax rate (or the optimal government size of spending) of developing countries should be greater than developed ones. These two results are consistent with many observations. For example, World Bank (1989, p.55) observes that governments of developing countries intervene their credit markets to a greater extent than do developed ones.[5]

Moreover, Karras (1996) estimates the optimal government size for 118 countries under the condition that the marginal productivity of government services is equal to the fraction of output absorbed by government services. The study finds

natural for the government to subsidize the screening cost. As shown below, the screening cost subsidy directly raises the quantity of loans in the state of screening and hence can raise the lending volume to a more efficient level.

[5] As is observed by World Bank (1989, p.55), development finance institutions (DFIs) are created and supported by the government of developing countries, which are mandated to apply interest rate and credit controls and to offer long-term finance to particular sector. Furthermore, "[g]overnment in high-income countries also intervened in their financial system. Although they exerted some influence over the flow of credit, interest rate and credit controls were less extensive than in developing countries." (World Bank, 1989, p. 55)

that the optimal government size (in terms of maximizing economic growth) is relatively larger for non-OECD countries than for OECD ones. Specifically, the optimal government size is 22% for non-OECD countries and 14% for OECD countries. Similarly, the optimal government size is 18% for countries in Europe, 25% for countries in Asia, and 16% for countries in North America.[6]

Following Section 1, Section 2 presents the model economy and Section 3 derives the equilibrium credit contracts for a given ratio of government subsidy and a given tax rate. In Section 4, we explore the optimal subsidy ratio and the optimal tax rate that maximize economic growth. We also investigate how a change in the financial sector efficiency influences the optimal subsidy ratio as well as the optimal tax rate. Section 5 concludes.

2. Model

Consider a model economy consisting of an infinite sequence of two-period-lived overlapping generations (OG).[7] Agents of each generation are identical in size and composition, and are divided into lenders/workers and borrowers/entrepreneurs. For simplicity, each population of lenders and borrowers under each generation is normalized to a continuum of unity; hence, the population of each generation has a measure of 2. Time is discrete and indexed by t=0, 1... The economy has two goods: a nonstorable consumption good (output) and a capital good. For simplicity, it is assumed that both lenders and borrowers are risk neutral and care only old-age consumption.

Lenders are endowed with a unit of labor when young and nothing when old. The labor endowment is inelasticitly supplied to firm to generate a competitively determined wage income. For simplicity, it is assumed that both lenders and borrowers are risk neutral and care only old-age consumption. To consume in the

[6] Ram (1986) separates a country's production into public sector and private sector production and finds that the productivity of the public sector is stronger in low-income (developing) countries than in high-income countries. Since economic growth is positively related to the productivity of the public sector, this result implies that the optimal size of the public (government) sector should be larger in low-income countries. Laopodis (2001) reports a similar result.

[7] The model economy is slightly modified from Bose and Cothren (1996) and Ho and Wang (2005).

old period, each young lender must loan to a borrower in exchange for output in the next period for consumption. To loan to borrowers, the young lender can enter into credit market after receiving young wage income. Similar to Bose and Cothren (1996) and Ho and Wang (2005), the large number of lenders implies that competition among lenders induce them to offer the most competitive contracts to borrowers and thus each lender earns a competitively-determined rate of returns from lending.

Each borrower is endowed with a risky capital project when young and become a firm operator when old. The firm operator at $t+1$ can produce y_{t+1} units of consumption good at the beginning of period $t+1$ according to the following production function:

$$y_{t+1} = G_{t+1}^{\eta} k_{t+1}^{\gamma} l_{t+1}^{1-\gamma},\ \gamma \in (0,1),\ \eta \in (0,1). \tag{1}$$

where k_{t+1} and l_{t+1} are per-firm capital stock and labor employed, respectively, and G_{t+1} is the aggregate government provision of public capital. Both types of private and public capital are fully depreciated after one period of use. Note that $l_{t=1} = l = 1$ for any period, as the number of firms (which is equal to the population of old borrowers) is equal to the number of workers (which is the population of young lenders). Following growth literature (e.g., Romer, 1986), it is assumed that $\eta = 1-\gamma$, indicating that the output production technology displays constant returns to scale in G_{t+1} and k_{t+1}. Assuming that factor markets are competitive, eq. (1) implies that the rental rates of labor as well as capital are given as

$$w_{t+1} = (1-\gamma) G_{t+1}^{1-\gamma} k_{t+1}^{\gamma} \tag{2}$$

and

$$\rho_{t+1} = \gamma G_{t+1}^{1-\gamma} k_{t+1}^{\gamma-1}, \tag{3}$$

where $l_{t+1} = l = 1$ has been substituted in eqs. (2) and (3).

To produce output at $t+1$, the young borrower must implement her capital project at t with the input borrowed from a lender. According to the probability of success, borrowers' capital projects are classified into two types: high risk (type *H*) projects or low risk (type *L*) ones. Specifically, suppose that a young borrower with a type $i, i = H, L,$ project borrows b_t units of output at t from a lender can produce an amount of capital at the beginning of the next period (denoted as Λ_{t+1}) that is

equal to

$$\Lambda_{t+1} = \begin{cases} Qb_t^{\beta}\bar{b}_t^{1-\beta} & \text{with probablity } p_i \\ 0 & \text{with probability } 1-p_i \end{cases} \tag{4}$$

where $Q > 0$ is a technolgical parameter, $\bar{b}_t$ is the average units of output borrowed in the economy by each borrower in the credit market, and $\beta \in (0,1)$ is a parameter that governs the productivities of b_t and $\bar{b}_t$. Note that the borrower's output level of capital production in the event of success (with probability p_i) depends not only on the amount of output borrowed by the borrower herself but also the average amount borrowed in the credit market, implying that there is externality in the credit market. As can be seen below, the average amount borrowed under the credit market equilibrium is directly related to b_t and hence the capital production technology displays constant returns to scale (in terms of the amount borrowed). This together with the production technology in eq. (1) ensures that both production technologies display constant returns to scale, which is required to obtain sustainable balanced growth path in the growth literature.[8] Moreover, it is assumed that $p_L > p_H$; hence, borrowers whose projects are type L (type H) are low-risk (high-risk) borrowers. Asymmetric information arises in this context as borrowers' risk type is private information.

The government finances its expenditure by taxing output at a rate τ. Assuming that the government maintains a balanced budget at each point of time, the government budget constraint is given as

$$G_{t+1} = \tau y_t - S_t, \tag{5}$$

[8] According to eqs. (1) and (4), both production activities display constant returns to scale for the economy as a whole. In OG models without explicitly modeling loan demand for risky capital investment, it is usually assumed that agent can convert a unit of time-t output (i.e., savings) into a unit of time-$t+1$ capital. This implies that capital production displays constant return to scale (for each agent as well as for the economy as a whole). Under such a setting, the capital stock at $t+1$ is equal to agents' savings at t, which is determined by agents' preference as well as the rate of return from savings. This together with an "Ak" type of output production technology like eq. (1) results in sustainable growth. In this paper, the loan demand for risky capital investment is explicitly modeled and an endogenously determined size of capital loan is highlighted. For this purpose, we impose a capital production technology that displays diminishing returns to scale to each borrower (and allow the borrower to choose the size of loans for capital investment) and constant returns to scale for the economy as a whole. This is exactly implied by eq. (4).

where S_t refers to the aggregate amount of loan subsidies by the government. As Bose and Cothren (1996) and Ho and Wang (2005), the presence of asymmetric information in credit market will lead to costly screening that places considerable strain on capital investment and thus economic growth. To ease this costly activity, we consider the case in which the government subsidizes a fraction s of screening costs for each screened loan at each period below.[9]

3. Loan Contracts and Credit Market Equilibrium

Recall that each lender receives wage income w_t when young but cares only for old-age consumption. To consume at the old age, the young lender at t enters into the credit market by offering competitive contracts to borrowers and hence earning a competitively-determined rate of returns (denoted as R_t). In this section, we first follow Bose and Cothren (1996) by deriving loan contracts under the separating equilibrium for a given R_t. This gives rises to the loan demand. By equating the demand of loans to the supply of loans (which is equal to young lenders' after-tax wage $(1-\tau)w_t$), we can obtain the equilibrium R_t.

As in Bose and Cothren (1996), the separating equilibrium displays self-selection of borrowers according to contracts accepted. To this end, each lender, taking the market-determined rate of returns R_t as given, announces two contracts: a contract that is intended for type H borrowers (denoted as C_t^H) and a contract that is intended for the type L borrowers (denoted as C_t^L). Though borrowers' risk type is private information, a lender can correctly discover the borrower's risk type by employing a costly screening technology that incurs δ units of output to the lender per unit lent. Given this screening technology, self selection of borrowers, as shown below, can emerge by offering contracts that specify a probability of screening and a screened borrower who is caught lying on her risk type will be refused to a loan.

Denote the loan contracts offered by the bank at t as $C_t^i = (\phi_t^i,\ R_{st}^i,\ b_{st}^i,\ R_{nt}^i,\ b_{nt}^i)$, $i = H, L$, where $\phi_t^i < 1$ is the probability that a borrower who applies for C_t^i will be screened and $R_{st}^i\ (R_{nt}^i)$ and $b_{st}^i\ (b_{nt}^i)$ are the loan rate and the loan quantity

[9] The relationship between S_t and s_t will be given after the equilibrium contracts are obtained.

received by the type i borrower, respectively, when the borrower is screened (not screened). We now determine the loan contracts under the separating equilibrium.

The expected utility of a type i borrower who reveals her true risk type by applying for the contract C_t^i from a lender at t is given as

$$\phi_t^i p_i\left[Q(b_{st}^i)^\beta \bar{b}_t^{1-\beta}(1-\tau)\rho_{t+1} - b_{st}^i R_{st}^i\right]$$
$$+\left(1-\phi_t^i\right)p_i[Q(b_{nt}^i)^\beta \bar{b}_t^{1-\beta}(1-\tau)\rho_{t+1} - b_{nt}^i R_{nt}^i]. \tag{6}$$

With the probability ϕ_t^i, the lender will screen the borrower and the borrower in this event receives b_{st}^i with a loan rate R_{st}^i. By implementing her project with an amount of b_{st}^i, the borrower can produce $Q(b_{st}^i)^\beta \bar{b}_t^{1-\beta}$ units of capital (and hence $Q(b_{st}^i)^\beta \bar{b}_t^{1-\beta}(1-\tau)\rho_{t+1}$ units of after-tax output) at $t+1$ with probability p_i. In this case, the borrower must pay $b_{st}^i R_{st}^i$ units of output to the lender as interest payment and consume the remaining. Thus, the first part of eq. (6) is the expected consumption of the borrower. Similarly, the second part of eq. (6) is the expected amount of after-tax output the borrower can consume when she is not screened.

To induce self selection of borrowers, the following incentive constraints must hold:

$$\phi_t^H p_H\left[Q(b_{st}^H)^\beta \bar{b}_t^{1-\beta}(1-\tau)\rho_{t+1} - b_{st}^H R_{st}^H\right]$$
$$+(1-\phi_t^H)p_H[Q(b_{nt}^H)^\beta \bar{b}_t^{1-\beta}(1-\tau)\rho_{t+1} - b_{nt}^H R_{nt}^H$$
$$\geq (1-\phi_t^L)p_H[Q(b_{nt}^L)^\beta \bar{b}_t^{1-\beta}(1-\tau)\rho_{t+1} - b_{nt}^L R_{nt}^L. \tag{7}$$

and

$$\phi_t^L p_L\left[Q(b_{st}^L)^\beta \bar{b}_t^{1-\beta}(1-\tau)\rho_{t+1} - b_{st}^L R_{st}^L\right]$$
$$+(1-\phi_t^L)p_L[Q(b_{nt}^L)^\beta \bar{b}_t^{1-\beta}(1-\tau)\rho_{t+1} - b_{nt}^L R_{nt}^L$$
$$\geq (1-\phi_t^H)p_L[Q(b_{nt}^H)^\beta \bar{b}_t^{1-\beta}(1-\tau)\rho_{t+1} - b_{nt}^H R_{nt}^H. \tag{8}$$

The LHS of eq. (7) is the expected utility of a type H borrower who reveals her risk type by applying for C_t^H, while the RHS of eq. (7) is the counterpart when the borrower pretends as a type L borrower by applying for C_t^L. Under eq. (7), a type H borrower has no incentive to pretend as a type L one by applying for C_t^L. Similarly,

eq. (8) prevents a type L borrower from pretending as a type H borrower. Under the separating equilibrium, at least one of eqs. (7) and (8) must hold with strict inquality.

Moreover, competition among lenders also implies that each lender earns a market-determined rate of returns, R_t, form lending to a borrower. Note that the lender is expected to receive $\phi_t^i p_i R_{st}^i b_{st}^i + (1-\phi_t^i) p_i R_{nt}^i b_{nt}^i$ units of output at $t+1$ from the borrower. Note also that the amount of resources needed to finance a type i borrower in the event of screening is equal to $b_{st}^i/[1-\delta(1-s)]$.[10] Thus, given the probability of screening ϕ_t^i the expected amount of resources needed for a lender to finance a type i borrower is equal to $\{\phi_t^i b_{st}^i/[1-\delta(1-s)] + (1-\phi_t^i) b_{nt}^i\}$. As the market-determined rate of returns is R_t, the zero economic profit constraint of a lender from lending to a borrower is given as

$$\phi_t^i p_i R_{st}^i b_{st}^i + \left(1-\phi_t^i\right) p_i R_{nt}^i b_{nt}^i = \{\frac{\phi_t^i b_{st}^i}{1-\delta(1-s)} + (1-\phi_t^i) b_{nt}^i\} R_t. \tag{9}$$

As Bencivenga and Smith (1993) and Bose and Cothren (1996), competition among lenders ensures that the separating equilibrium contracts are obtained by maximizing eq. (6) subject to eqs. (7), (8) and (9).[11] The equilibrium loan contracts under the separating equilibrium can be defined as below:

Definition. The equilibrium contract in the credit market at t is characterized by a pair of loan contract (C_t^L, C_t^H) in which $C_t^i = \left(\phi_t^i,\ R_{st}^i,\ b_{st}^i,\ R_{nt}^i,\ b_{nt}^i\right), i = H$,that maximizes eq. (6) subject to eqs. (7), (8), and (9), taking the factor prices (ρ_{t+1} and w_t), the average amount borrowed ($\bar{b}_t$), and the market-determined rate of returns R_t as given.

To find the separating equilibrium, first rewrite eq. (9)

$$\frac{\phi_t^i R_{st}^i b_{st}^i + \left(1-\phi_t^i\right) R_{nt}^i b_{nt}^i}{\dfrac{\phi_t^i b_{st}^i}{1-\delta(1-s)} + (1-\phi_t^i) b_{nt}^i} = \frac{R_t}{p_i}.$$

Note that R_t/p_i is the expected rate of interest the type i borrower (who reveals her

[10] Recall that screening absorbs δ units of resources per unit lent and the government subsidizes s_t fraction of the screening cost. The screening cost is en ante; hence, for evey one unit received by a borrower, the amount spent by a lender, inclusive of the screening cost, is equal to $\frac{1}{[1-\delta(1-s)]}$.

[11] In fact, our setting implies that maximizing a borrower's expected utility is equivalent to maximizing the lender's expected utility. See below for further discussion.

true risk type by applying for C_t^L) must pay to the lender, becasue $\phi_t^i R_{st}^i b_{st}^i + (1-\phi_t^i) R_{nt}^i b_{nt}^i$ is the amount of output the borrower must pay to the lender at $t+1$ (when the project is successful) and $\phi_t^i b_{st}^i/[1-\delta(1-s)] + (1-\phi_t^i) b_{nt}^i$ is the amount of output the lender loans to the borrower at *t*. Since $p_L > p_H$, the expected rate of interest in C_t^H is higher than the one in C_t^L. This gives type *H* borrowers the incentive to pretend as type *L* ones by applying for the contract C_t^L (and enjoying a lower interest payment). By contrast, type *L* borrowers have no incentive to pretends as type *H* ones. In other words, the incentive constraint in eq. (8) is always held with a strict inequality under eq. (9).

The expected utility of a type *i* borrower in applying for C_t^i (i.e., eq. (6)) is a linear combination of the expected utilities (i.e. expected consumption) in the events of screening and non-screening. As a result, to find the optimal contracts for the borrower one can first derive the optimal quantities of loans under each event (i.e., b_{st}^i and b_{nt}^i) by taking the loan rates (R_{st}^i and R_{nt}^i) as given. Once the optimal loan quantities are obtained, the equilibrium values of probability of screening (ϕ_t^i) and loan rates (R_{st}^i and R_{nt}^i) can be derived from the incentive contraint in eq. (7) and the zero economic profit constraint in eq. (9). Taking R_{st}^i and R_{nt}^i as given, the optimal loan quantities that maximizes the expected utlities for each event are given as

$$b_{st}^i = [\frac{R_{st}^i}{Q\beta(1-\tau)\rho_{t+1}}]^{\frac{1}{\beta-1}} \bar{b}_t. \tag{10}$$

and

$$b_{nt}^i = [\frac{R_{nt}^i}{Q\beta(1-\tau)\rho_{t+1}}]^{\frac{1}{\beta-1}} \bar{b}_t. \tag{11}$$

Since screening is costly, the fact that type *L* borrowers will not apply for C_t^H implies that the lender should not screen the borrower who applies for the contract C_t^H.[12] Consequently,

$$\phi_t^H = 0. \tag{12a}$$

[12] If the lender screens the borrower who applies for C_t^H, then the zero economic profit constraint implies that the loan rate will be relatively higher in this case. This will reduce the optimal loan quantity and hence a lower expected utility to the borrower who applies for C_t^H.

Substituting this and eq. (11) into eq. (9), we can find that

$$R_{nt}^{H} = \frac{R_t}{p_H}. \tag{12b}$$

and hence

$$b_{nt}^{H} = [\frac{R_t}{p_H Q\beta(1-\tau)\rho_{t+1}}]^{\frac{1}{\beta-1}}\bar{b}_t. \tag{12c}$$

We now determine the contract C_t^L. Using eqs. (10) and (11) for type L borrowers, eq. (6) can be rewritten as

$$p_L[\phi_t^L R_{st}^L b_{st}^L + (1-\phi_t^L)R_{nt}^L b_{nt}^L]\frac{1-\beta}{\beta}. \tag{13}$$

Since the expected utility of a honest type L borrower is a linear combination of $R_{st}^L b_{st}^L$ and $R_{nt}^L b_{nt}^L$, we consider two cases to induce the terms of Contract C_t^L. As the first case, suppose that the lender's offer satisfies that $R_{st}^L b_{st}^L > R_{nt}^L b_{nt}^L$. In this case, eq. (13) is increasing in the screening probability ϕ_t^L. Given this, it is optimal to set

$$\phi_t^L = 1. \tag{14a}$$

implying that the lender always screen the borrower who applies for the contract C_t^L. Substituting $\phi_t^L = 1$ into eq. (9), we derive

$$R_{st}^L = \frac{R_t}{p_L[1-\delta(1-s)]} \tag{14b}$$

and hence

$$b_{st}^L = \left\{\frac{R_t}{Q\beta p_L(1-\tau)\rho_{t+1}}\right\}^{\frac{1}{\beta-1}}\bar{b}_t. \tag{14c}$$

Note that if $\phi_t^L = 1$, then the incentive constraint in eq. (7) always hold with a strict inequality. As a result, eqs. (14a-c) determine the contract C_t^L for the case of $R_{st}^L b_{st}^L > R_{nt}^L b_{nt}^L$.[13]

If, on the other hand, $R_{st}^L b_{st}^L \leq R_{nt}^L b_{nt}^L$, then the expected utility of a type L borrower (who reveals her type by applying for C_t^L is decreasing in ϕ_t^L. Hence, ϕ_t^L should be set as small as possible or, equivalently, $1-\phi_t^L$ should be set as large

[13] We do not need to solve for b_{nt}^L and R_{nt}^L, as all borrowers who applies for C_t^L are screened.

as possible, making the incentive constraint in eq. (7) binding. Substituting eqs. (12a-c) and (11) into the binding eq. (7) leads

$$1-\phi_t^L=\frac{b_{nt}^H R_{nt}^H}{b_{nt}^L R_{nt}^L}. \tag{15}$$

for the contract C_t^L. Eq. (15) indicates that $1-\phi_t^L$ is decreasing in $b_{nt}^L R_{nt}^L$. Thus, $b_{nt}^L R_{nt}^L$ should be set as small as possible in order to maximize $1-\phi_t^L$. Since $R_{st}^L b_{st}^L \leq R_{nt}^L b_{nt}^L$, this further implies that $R_{st}^L b_{st}^L$ should be equal to $R_{nt}^L b_{nt}^L$ in this case. As eqs. (10) and (11) indicate that b_{nt}^L and b_{st}^L are functions of R_{nt}^L and R_{st}^L, respectively, $R_{st}^L b_{st}^L = R_{nt}^L b_{nt}^L$ implies that $R_{nt}^L = R_{st}^L$ and hence $b_{nt}^L = b_{st}^L$. Using this result, the zero economic profit constraint can be derived as

$$\phi_t^L p_L R_{st}^L b_{st}^L + (1-\phi_t^L) p_L R_{nt}^L b_{nt}^L = p_L R_{st}^L b_{st}^L = p_L R_{nt}^L b_{nt}^L$$
$$= \{\frac{\phi_t^L b_{st}^L}{1-\delta(1-s)} + (1-\phi_t^L) b_{nt}^L\} R_t$$

Substituting eqs. (10) and (11) into the above expression, we have

$$R_{nt}^L = R_{st}^L = \frac{[\frac{\phi_t^L}{1-\delta(1-s)} + (1-\phi_t^L)] R_t}{p_L}. \tag{16a}$$

It remains to determine the equilibrium value of ϕ_t^L in this latter case. Using eq. (16a), one sees that

$$b_{nt}^L = b_{st}^L = b_t^L = \{\frac{\left[\frac{\phi_t^L}{1-\delta(1-s)} + (1-\phi_t^L)\right] R_t}{Q\beta(1-\tau)\rho_{t+1} p_L}\}^{\frac{1}{\beta-1}} \bar{b}_t. \tag{16b}$$

Then, substituting $R_{st}^L b_{st}^L$ (or $R_{nt}^L b_{nt}^L$) into eq. (15), we have

$$1-\phi_t^L = \left\{\frac{p_H[1-\delta(1-s)(1-\phi_t^L)]}{p_L[1-\delta(1-s)]}\right\}^{\frac{\beta}{1-\beta}}. \tag{16c}$$

The LHS of eq. (16c) is decreasing in ϕ_t^L while the RHS of eq. (16c) is increasing in ϕ_t^L. Moreover, the RHS of eq. (16c) is equal to $(p_H/p_L)^{\beta/(1-\beta)}$ if ϕ_t^L and $\{\frac{p_H}{p_L[1-\delta(1-s)]}\}^{\beta/(1-\beta)}$ if $\phi_t^L = 1$. Hence, there must be a unique ϕ_t^L (denoted as ϕ_t^*, $\phi_t^* \in (0,1)$) that satisfies eq. (16c).

Eqs. (16a-c) determine the contract C_t^L for the case of $R_{st}^L b_{st}^L \leq R_{nt}^L b_{nt}^L$. In

comparison with the case of $R_{st}^L b_{st}^L > R_{nt}^L b_{nt}^L$ (i.e., eqs. (14a-c)), it is clear that the loan rate in the eq. (16a) is less than that in eq. (14b) and the loan quantity in eq. (16a) is higher than that in eq. (14c). These two imply that the expected utility of the borrower is higher in the case of $R_{st}^L b_{st}^L \leq R_{nt}^L b_{nt}^L$ than the one in the case of $R_{st}^L b_{st}^L > R_{nt}^L b_{nt}^L$. As a result, the equlibrium contract to the type L borrower comprises eqs. (16a-c). The following proposition summarizes the equilibrium contract:

Proposition 1. The equilibrium contract at period t for type H borrowers is characterized by $C_t^H = (R_{nt}^H,\ b_{nt}^L)$ with $R_{nt}^H = \frac{R_t}{p_H}$, $b_{nt}^H = [\frac{R_t}{p_H Q\beta(1-\tau)\rho_{t+1}}]^{\frac{1}{\beta-1}}\bar{b}_t$ and no screening, while the equilibrium contract for type L is characterized by $C_t^L = (\phi_t^*,\ R_{st}^L,\ b_{st}^L,\ R_{nt}^L,\ b_{nt}^L)$ with ϕ_t^* being satisfied by $1-\phi_t^L = \left\{\frac{p_H[1-\delta(1-s)(1-\phi_t^L)]}{p_L[1-\delta(1-s)]}\right\}^{\frac{\beta}{1-\beta}}$, $R_{st}^L = R_{nt}^L = \frac{[\frac{\phi_t^L}{1-\delta(1-s)}+(1-\phi_t^L)]R_t}{p_L}$, and $b_{st}^L = b_{nt}^L = b_t^L = \{\frac{\left[\frac{\phi_t^*}{1-\delta(1-s)}+(1-\phi_t^*)\right]R_t}{Q\beta(1-\tau)\rho_{t+1}p_L}\}^{\frac{1}{\beta-1}}\bar{b}_t$.

To derive a closed form solution for ϕ_t^*, we assume that $\beta = 0.5$ in the ensuing analysis. Under this assumption, the equilibrium screening probability is given as

$$\phi_t^* = \phi^* = 1 - \frac{p_H}{p_L[1-\delta(1-s)] + p_H\delta(1-s)}$$
$$= \frac{(p_L - p_H)[1-\delta(1-s)]}{p_L[1-\delta(1-s)] + p_H\delta(1-s)}, \qquad (16d)$$

which implies that b_t^L is given as

$$b_t^L = \{\frac{R_t}{Q\beta(1-\tau)\rho_{t+1}[p_L\big(1-\delta(1-s)\big) + p_H\delta(1-s)]}\}^{-2}\bar{b}_t. \qquad (16e)$$

The following lemma summarizes the direct effects of changes in s and δ on ϕ^* and b_t^L for given R_t and $\bar{b}_t$.

Lemma 1. For given R_t and $\bar{b}_t$, (i) an increase in the subsidy ratio leads to an increase in the amount borrowed by type L borrowers ($\partial b_t^L/\partial s > 0$) and the

probability of screening ($\partial\phi^*/\partial\delta > 0$); (ii) an increase in the screening cost δ decreases the amount borrowed by type L borrowers and the probability of screening.

Intuitively, for given R_t and $\bar{b}_t$, an increase in the subsidy ratio s will reduce the cost associated with lending to type L borrowers (to lenders). This will give type H borrowers more incentive to apply for C_t^H, other thing being equal. In the separating equilibrium, the probability of screening must increase to prevent type H borrowers from mimicking type L borrowers. By contrast, an increase in the screening cost will increase the cost associated with lending to type L borrowers. Under the zero-profit constraint, the lender must raise R_t^L and hence decrease b_t^L. A decrease in b_t^L implies that the expected consumption of type H borrowers in applying for C_t^L also decrease. This given type H borrowers less incentive to apply for C_t^L. As a result, the equilibrium probability of screening should be reduced.

It is worth noting that changes in s and δ for given R_t and $\bar{b}_t$ have no direct effects on the amount borrowed by type H borrowers, because the contract C_t^H is not subject to screening. However, since changes in s and δ affect the demand of loans of type L borrowers, they will influence R_t which will further affect the amount borrowed by type H borrowers.

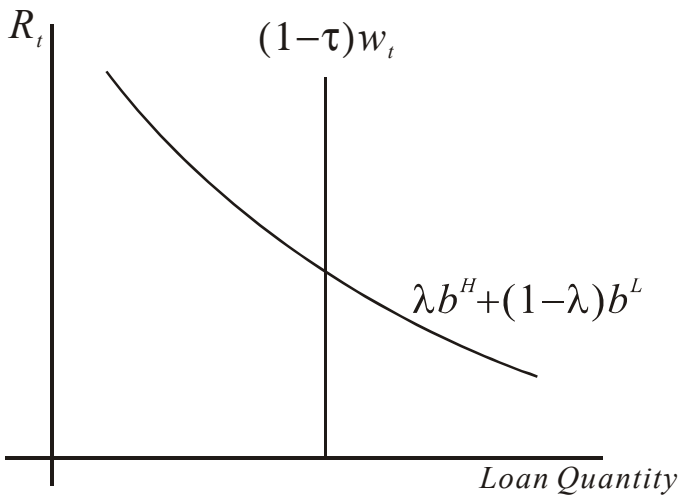

Figure 1. The determination of R_t

We now determines the equilibrium R_t under the assumption of $\beta = 0.5$. From the equilibrium contracts, we can derive the demand of loans given by

$\lambda b_t^H + (1-\lambda)[\phi^* b_{st}^L + (1-\phi^*) b_{nt}^L] = \lambda b_t^H + (1-\lambda) b_t^L$.[14] As the population of borrowers is normalized to one, the demand of loans is also the average amount borrowed by each borrower, $\bar{b}_t$. On the other hand, the supply of loans is equal to the after-tax wage income of young lenders, $(1-\tau)w_t$. Using this result, Figure 1 depicts the supply and demand of loans. The credit market equilibrium implies that

$$\lambda b_t^H + (1-\lambda)[\phi^* b_t^L + (1-\phi^*) b_t^L] = \lambda b_t^H + (1-\lambda) b_t^L = \bar{b}_t = (1-\tau)w_t,$$

where $b_{nt}^L = b_{st}^L = b_s^L$ has been substituted. Substituting b_t^H and b_t^L into the above equation, we obtain the market-determined rate of returns R_t as

$$R_t = Q\beta\rho_{t+1}\{\lambda p_H^2 + (1-\lambda)[p_L\big(1-\delta(1-s)\big) + p_H\delta(1-s)]^2\}^{0.5}, \qquad (17)$$

which leads to the following result:

Lemma 2. (i) An increase in the subsidy ratio *s* raises the market-determined rate of returns R_t; (ii) an increase in the screening cost δ reduces the market-determined rate of return R_t.

Recall that, for given R_t and $\bar{b}_t$, an increase in the subsidy ratio raises the loan demand of type *L* borrowers. As the loan supply is independent of the subsidy ratio, an increase in the subsidy ratio will increase the equilibrium rate of interest R_t. By contrast, an increase in the screening cost that reduces b_s^L will decrease the market-determined rate of return R_t.

Using eq. (17), we can derive the amount borrowed by type *H* borrowers and type *L* borrowers as follows:

$$b_t^H = \frac{p_H^2}{\lambda p_H^2 + (1-\lambda)\big[p_L\big(1-\delta(1-s)\big) + p_H\delta(1-s)\big]^2}(1-\tau)w_t$$

$$\equiv b_h(1-\tau)w_t \qquad (18)$$

and

$$b_t^L = \frac{\big[p_L\big(1-\delta(1-s)\big) + p_H\delta(1-s)\big]^2}{\lambda p_H^2 + (1-\lambda)\big[p_L\big(1-\delta(1-s)\big) + p_H\delta(1-s)\big]^2}(1-\tau)w_t$$

[14] Recall that $b_{nt}^L = b_{st}^L = b_s^L$; hence, the demand of loans for type *L* borrowers, $(1-\lambda)[\phi^* b_{st}^L + (1-\phi^*) b_{nt}^L] = (1-\lambda) b_t^L$.

$$\equiv b_l(1-\tau)w_t, \tag{19}$$

where

$$b_h \equiv \frac{p_H^2}{\lambda p_H^2 + (1-\lambda)\left[p_L\left(1-\delta(1-s)\right) + p_H\delta(1-s)\right]^2}$$

and

$$b_l \equiv \frac{\left[p_L\left(1-\delta(1-s)\right) + p_H\delta(1-s)\right]^2}{\lambda p_H^2 + (1-\lambda)\left[p_L\left(1-\delta(1-s)\right) + p_H\delta(1-s)\right]^2}$$

respectively represent the fraction of loan supply $(1-\tau)w_t$ allocated to (borrowed by) type *H* and type *L* borrowers,.

The following lemma characterize the effects of changes in the subsidy ratio *s* and the screening cost δ on the equilibrium probability of screening ϕ^* as well as the fraction borrowed by type *H* and type *L* borrowers, after considering their effects on the market-determined R_t.

Lemma 3. An increase in the subsidy ratio *s* leads to (i) an increase in the fraction of loan supplied allocated to type *L* borrowers (i.e., b_l); (ii) a decrease in the fraction of loan supplied allocated to type *H* borrowers (i.e., b_h). An increase in the screening cost δ leads to (i) a decrease in the fraction of loan supplied allocated to type *L* borrowers (i.e., b_l); (ii) an increase in the fraction of loan supplied allocated to type *H* borrowers b_h (i.e., b_h).

Recall that an increase in the subsidy ratio directly raises b_t^L for given R_t and $\bar{b}_t$ (Lemma 1). Nevertheless, such an increase will lead to an increase in R_t for a given $(1-\tau)w_t$ (Lemma 2), which will indirectly reduce b_t^L as implied by eq. (16e). As the direct effect dominates the indirect one, an increase in the subsidy ratio will increase the amount borrowed by type *L* borrowers (b_t^L) for a given $\bar{b}_t$. Since the average amount borrowed by borrowers, $\bar{b}_t$, is equal to the amount of loan supplied $(1-\tau)w_t$, an increase in the subsidy ratio, for a given $(1-\tau)w_t$, will increase the fraction of $(1-\tau)w_t$ allocated to type *L* borrowers (i.e. b_l). By contrast, an increase in the screening cost will directly decreases b_t^L for a given R_t

and such an increase leads to a decrease in R_t. This latter effect will indirectly increase b_t^L according to eq. (16e). Again, Lemma 3 implies that the direct effect dominates the indirect effect so that an increase in the screening cost leads to a decrease in b_l.

For a given amount of loan supplied $(1-\tau)w_t$, any change that raises the fraction borrowed by type *L* borrowers must be associated with a reduction in the fraction borrowed by type *H* borrowers. As a result, an increase in the subsidy ratio that raises b_l must decrease b_h. Similarly, an increase in the screening cost δ that reduces b_l must be associated with an increase in the fraction borrowed by type *H* borrowers. Alternatively, an increase in the subsidy ratio that leads to an increase in R_t (Lemma 2) will indirectly reduce b_t^H for a given $\bar{b}_t$ according to eq. (12c). A decrease in b_t^H for a given $\bar{b}_t$ is equivalent to a decrease in the fraction borrowed by type *H* borrowers (i.e. b_h) for a given amount of loan supplied $(1-\tau)w_t$. Similarly, an increase in the screening cost that reduces R_t will increase the amount borrowed by type *H* borrowers.

Results of Lemma 3 have some important implications. Recall that the probability of success for type *L* borrowers' projects is higher than that of type *H* borrowers'. This implies that type *L* borrowers are more efficient in capital production than type *H* borrowers. As a result, if the government's subsidy is able to raise the fraction of loan supplied allocated to type *L* borrowers b_l (and reduce the fraction allocated to type *H* borrowers b_h), this type of subsidy can enhance private capital investment and hence economic growth. Note that the marginal effect of an increase in the subsidy ratio in rising b_l must be diminishing; otherwise, the optimal subsidy ratio is equal to one. If the subsidy ratio is equal to one, then the problem of asymmetric information simply disappears. As this is not the case in reality, we thus impose the following assumption in the ensuing analysis:

Assumption 1. The marginal effect of an increase in the subsidy ratio in rising b_l displays diminishing (i.e., $\partial^2 b_l/\partial s^2 < 0$).[15]

[15] The condition for $\partial^2 b_l/\partial s^2 < 0$ is $(1-\lambda)4x^2 > \lambda p_H^2 + (1-\lambda)x^2$. See Appendix.

Assumption 1 also implies that $\partial^2 b_h/\partial s^2 > 0$ and $\partial^2 \phi^*/\partial s^2 < 0$. Under Assumption 1, it is likely that the effect of an increase in the subsidy ratio on rising b_l could dominate (be dominated by) such the effect on reducing b_h for small (large) levels of s, ensuring the existence of an optimal subsidy ratio in terms of enhancing private capital investment.

Note that an increase in the screening cost that reduces the fraction allocated to type L borrowers b_l (and increase the fraction allocated type H borrowers b_h) will impede private capital production and economic growth. In this case, it may be optimal for the government to increase the subsidy ratio in order to facilitate capital investment when the screening cost increases. We will explore these issues in the next section.

4. Economic Growth and Optimal policies

From the equilibrium of credit market, the capital stock at $t+1$, k_{t+1}, can be obtained as

$$k_{t+1} = \lambda p_H Q(b_t^H)^{0.5} \bar{b}_t^{0.5} + (1-\lambda) p_L Q(b_t^L)^{0.5} \bar{b}_t^{0.5}.$$

Substituting eqs. (18) and (19) and noting that $\bar{b}_t = (1-\tau)w_t$ and $w_t = (1-\gamma)y_t$, we finally derive

$$\begin{aligned} k_{t+1} &= Q(1-\tau)\left[\lambda p_H {b_h}^{0.5} + (1-\lambda) p_L {b_l}^{0.5}\right] w_t \\ &= Q(1-\tau)(1-\gamma) y_t \left[\lambda p_H {b_h}^{0.5} + (1-\lambda) p_L {b_l}^{0.5}\right], \end{aligned} \tag{20}$$

As $p_L > p_H$, an increase in the subsidy ratio that raises b_l and reduces b_h may enhance private capital production.

Since the government subsidizes the screening cost at a rate of s, the total amount of subsidy S_t is given as

$$S_t = (1-\lambda) s \delta \phi^* b_t^L = (1-\lambda) s \delta \phi^* b_l (1-\tau) w_t. \tag{21}$$

Note that S_t can be viewed as the cost of government subsidy. Recall that $\partial \phi^*/\partial s > 0$ and $\partial b_t^L/\partial s > 0$; thus, an increase in the subsidy ratio s will increase the amount of output needed (or the cost) for the government subsidy. For a given

tax rate τ, an increase in the amount of resource needed for the government subsidy ratio will reduce the amount of public capital provided by the government. To ensure the existence of an optimal subsidy ratio in terms of government resource allocation between subsidy and public capital, we must impose the following assumption:

Assumption 2. $\frac{\partial^2 S_t}{\partial s^2} \geq 0$ for a given $(1-\tau)w_t$.

Assumption 2 indicates that the marginal effect of an increase in the subsidy ratio *s* in raising the amount of government subsidy (or the marginal cost of government subsidy) is constant or increasing. This assumption precludes the case in which the marginal cost of government subsidy is diminishing. If the marginal cost of subsidy is diminishing, the government may fully subsidize the screening cost to derive the lowest marginal cost of subsidy.

Substituting the above equation as well as $w_t = (1-\gamma)y_t$ into eq. (5), we derive the amount of public capital at $t+1$ as

$$G_{t+1} = y_t[\tau - (1-\gamma)(1-\tau)(1-\lambda)s\delta\phi^* b_l]. \tag{22}$$

We next derive the growth rate. Substituting eqs. (20) and (22) into eq. (1), we derive

$$y_{t+1} = \{y_t[\tau - (1-\gamma)(1-\tau)(1-\lambda)s\delta\phi^* b_l]\}^{1-\gamma}$$
$$\{Q(1-\tau)(1-\gamma)y_t\left[\lambda p_H {b_h}^{0.5} + (1-\lambda)p_L {b_l}^{0.5}\right]y_t\}^{\gamma}.$$

The growth rate is then derived as

$$\frac{y_{t+1}}{y_t} = g = [Q(1-\gamma)]^{\gamma}[\tau - (1-\tau)(1-\gamma)(1-\lambda)s\delta\phi^* b_l]^{1-\gamma}$$
$$(1-\tau)^{\gamma}[\lambda p_H {b_h}^{0.5} + (1-\lambda)p_L {b_l}^{0.5}]^{\gamma}, \tag{23}$$

which implies that

$$\ln g = \gamma \ln Q(1-\gamma) + (1-\gamma)\ln[\tau - (1-\tau)(1-\gamma)(1-\lambda)s\delta\phi^* b_l]$$
$$+ \gamma\{\ln(1-\tau) + \ln[\lambda p_H {b_h}^{0.5} + (1-\lambda)p_L {b_l}^{0.5}]\}. \quad (24)$$

The government chooses optimal τ and s to maximize the growth rate. The first order condition for selecting τ is derived as (the subscript τ represents the tax rate that is derived from the FOC of selecting the optimal τ)

$$\frac{(1-\gamma)[1+(1-\gamma)(1-\lambda)\delta s\phi^* b_l]}{\tau_\tau - (1-\tau_\tau)(1-\gamma)(1-\lambda)s\delta\phi^* b_l} = \frac{\gamma}{(1-\tau_\tau)}, \quad (25)$$

From Lemma 3, an increase in *s* raises $s\phi^* b_l$, which will further increase the LHS of eq. (25). As a result, eq. (25') implies that τ_τ is increasing in the subsidy ratio *s*.

Eq. (25) reveals an interesting result. If the government does not subsidize the screening cost, then the optimal tax rate is equal to $1-\gamma$ (the output elasticity of public capital), even though the screening cost is not equal to zero. This result is in sharp contrast to Ho and Wang (2005), but is consistent with Barro (1990).

Similarly, the first order condition for selecting *s* is given as (the subscript s represents the tax rate that is derived from the FOC of selecting the optimal s)

$$\frac{0.5\gamma[\lambda p_H b_h^{-0.5}\frac{\partial b_h}{\partial s} + (1-\lambda)p_L b_l^{-0.5}\frac{\partial b_l}{\partial s}]}{\lambda p_H {b_h}^{0.5} + (1-\lambda)p_L {b_l}^{0.5}}$$
$$= \frac{(1-\gamma)(1-\tau_s)(1-\gamma)(1-\lambda)\delta\frac{\partial(s\phi^* b_l)}{\partial s}}{\tau_s - (1-\gamma)(1-\tau_s)(1-\lambda)s\delta\phi^* b_l} \quad (26)$$

Under Assumption 1 and Lemma 3, the LHS of eq. (26) is decreasing in the subsidy ratio *s*. One the other hand, Assumption 2 and Lemma 3 indicate that the RHS of eq. (26) is increasing in *s*. As a result, eq. (26) implies that τ_s is also increasing in the subsidy ratio *s*.

The optimal values of τ and s are jointly determined by eqs. (25) and (26). To find the optimal values of τ and s, we first obtain the following result:

Lemma 4. If $s = 1$, then $\tau_s = 1 > \tau_\tau$.

Proof. See Appendix.

Given that τ_τ and τ_s are increasing in s and $\tau_s = 1 > \tau_\tau$ when $s = 1$, we obtain the following proposition that specifies the condition for interior solutions to optimal τ and s.

Proposition 2. If τ_s (derived from eq. (26)) is less than $1 - \gamma$ when $s = 0$, then there exists a unique pair of τ and s (denoted as τ^* and s^*) that maximize economic growth.

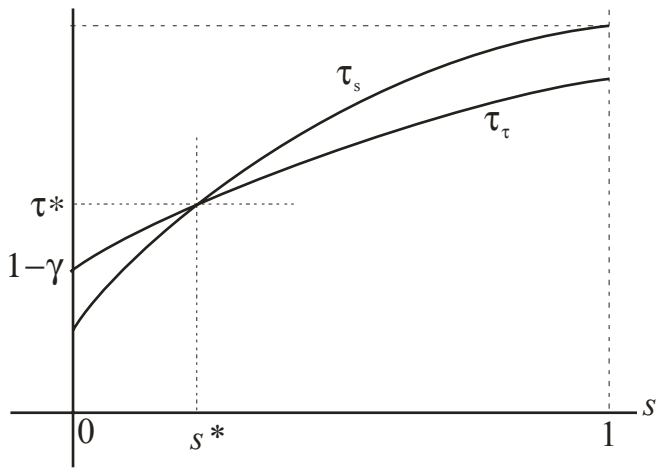

Figure 2. The subsidy ratio s and its relationship with τ_τ as well as τ_s

We depict τ_τ and τ_s as functions of s in Figure 2 under Proposition 2. Because τ_τ and τ_s are both increasing in s, and $\tau_s = 1 > \tau_\tau$ when $s = 1$, the locus of τ_τ must intersect with that of τ_s at once for $s \in (0,1)$ when $\tau_s > \tau_\tau$ holds for $s = 0$.

Finally, we examine the effects of an increase in the screening cost on the optimal τ^* and s^*. We first derive the following results.

Lemma 5. (i) $\frac{\partial \tau_\tau}{\partial \delta} = 0$ if $s = 0$; (ii) $\frac{\partial \tau_\tau}{\partial \delta} > 0$ if $s > 0$; (iii) $\frac{\partial \tau_s}{\partial \delta} < 0$ if $s = 0$; (ii) $\frac{\partial \tau_s}{\partial \delta} = 0$ if $s = 1$.

According to Lemma 5, an increase in the screening cost shifts the locus of τ_τ

(the locus of τ_s) up (down). As shown in Figure 3, we have the following result.

Proposition 3. An increase in the screening cost increases the optimal subsidy ratio and the tax rate.

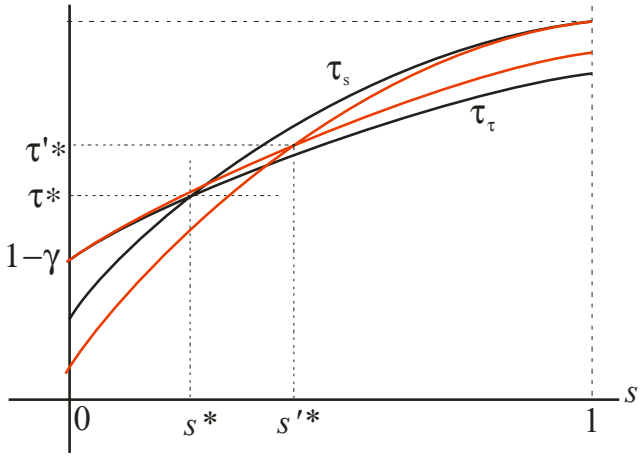

Figure 3. The effect of an increase in δ

Intuitively, an increase in the screening cost induces the government to increase its subsidy ratio. Because the government finances its subsidy by output taxation, an increase in the subsidy ratio is accompanied with an increase in the tax rate. The key result of Ho and Wang (2005) is that the optimal tax rate is negatively correlated with δ. Interestingly, by endogenously obtaining the optimal subsidy ratio s^*, this paper reaches an opposite conclusion---an increase in the screening cost leads to an increase in the optimal tax rate. The intuition behind this result, however, is straightforward. As an increase in the screening cost creates a larger distortion to private capital investment and the government subsidy is able to ease this distortion, it is optimal for the government to increase its subsidy ratio when the screening cost increases. An increase in the subsidy ratio, however, requires additional resources from the government, which can be fulfilled by increasing the tax rate.

It is worth noting that our results are consistent with observations of empirical studies. To see this, note that, similar to Ho and Wang (2005), the screening cost δ

can be viewed as an indicator of the efficiency of financial sector as well as the level of financial development, namely that a lower level of the screening cost corresponds to a more efficient financial sector and thus a more developed financial sector.[16]

Note also that developed countries possess a more developed financial sector than do developing ones.[17] Thus, Proposition 3 implies that developing countries should provide more credit subsidies than do developed ones. This is consistent with the observation of World Bank (1989). As developing countries intervene its financial sector more extensively than do developed ones, this further implies that the optimal tax rate (or equivalently, the optimal government size) should be larger in developing countries than in developed ones. Karras (1996), for example, estimates the optimal government size for 118 countries and demonstrates that the optimal government size (in terms of maximizing economic growth) is relatively larger for non-OECD countries than for OECD ones. Specifically, the optimal government size is 22% for non-OECD countries and 14% for OECD countries. Similarly, the optimal government size is 18% for countries in Europe, 25% for countries in Asia, and 16% for countries in North America.[18]

5. Conclusion

[16] Indeed, according to Bernanke (1983), the cost of financial intermediation is defined as the cost of channeling funds from lenders to borrowers, which includes the screening , monitoring, and accounting costs as well as other costs from bad loans. A lower cost of financial intermediation corresponds to a more efficient financial sector.

[17] Gurley and Shaw (1955) find that, in sharp contrast to developing countries, developed countries possess sophisticated and elaborate system of financial institutions which enhances the efficiency of resource allocation between lenders and borrowers. Goldsmith (1969), by comparing 36 countries over a period of a century, find that time periods with higher growth coincide with faster financial development. Thus, high income countries (developed countries), which result from high growth over a long period, possess a higher level of financial development.

[18] Ram (1986) separates a country's production into public sector and private sector production and finds that the productivity of the public sector is stronger in low-income (developing) countries than in high-income countries. Since economic growth is positively related to the productivity of the public sector, this result implies that the optimal size of the public (government) sector should be larger in low-income countries. Laopodis (2001) reports a similar result.

This paper examines the optimal tax rate (i.e. the optimal government size) in an simple endogenous growth model with the presence of asymmetric information and government credit subsidies. The main conclusion is that the government should increase its tax rate (its government size) when the screening cost increases. This is so because, first, the government relies on taxation to finance its credit subsidies and, second, it is optimal for the government to increase its credit subsidies when the screening cost increases. As a lower level of the screening cost corresponds to a more efficient financial sector and hence a more developed financial sector and developing countries usually possess a relatively less developed financial sector than do developed ones, this further implies that developing countries, as is observed by World Bank (1989), should intervene its credit market more extensively and hence its tax rate (and hence government size) should be larger than do developed ones. Though the main conclusion of this paper---developing countries should have a larger tax rate than developed ones---is in sharp contrast with Ho and Wang (2005), it is well consistent with observations of recent empirical works.

As a final remark, it is worth noting that Ho and Wang (2005), by calculating simple correlation coefficient, find a positive correlation between the level of financial development and the government size (the tax rate). This empirical evidence, however, should not be interpreted as violating the main conclusion of this paper. To see this, the indicators of financial development in Ho and Wang (2005), such as "private credit 1" and "private credit 2",[19] do not deduct credit that is stimulated by government credit subsidies.[20]

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[19] As in argued by De Gregiorio and Guidotti (1995), private credit is much more appropriate measure of financial development than other indicators. See also Levine et al. (2000) for this point.

[20] Note that, in Ho and Wang (2005), private credit 1 is defined by credit issued by deposit banks and non-bank institutions (% of GDP) while private credit 2 is credit issued by only deposit banks (% of GDP). Obviously, private credit that is stimulated by government-fund subsidies, as is shown by

Thus, the higher level of private credit 1 as well as private credit 2 may be caused by higher level of government credit subsidies. Indeed, as is shown, government credit subsidies, such as the interest rate subsidy in this paper, promote private credit by increasing the lending volume for type l borrowers. As a result, a positive correlation between private credit and the optimal government size is consistent with this paper, because a higher government size is a result of a higher level of government credit subsidies, which stimulates a higher level of private credit.

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Appendix

1. Note that $x = p_L$ if $s = 1$. Then, it is easy to verify that

$$\lambda p_H b_h^{-0.5} \frac{\partial b_h}{\partial s} + (1-\lambda) p_L b_l^{-0.5} \frac{\partial b_l}{\partial s} = 0 \qquad \text{if } s = 1.$$

As the result, the LHS of eq. (26) is equal to zero when $s = 1$. On the other hand, $\delta \frac{\partial (s\phi^* b_l)}{\partial s}$ is not equal to zero when $s = 1$. Thus, for eq. (26) to hold when $s = 1$, τ_s must be equal to one.

Re-state eq. (25) as follows:

$$\frac{(1-\gamma)[1+(1-\gamma)(1-\lambda)\delta s\phi^* b_l]}{\tau_\tau-(1-\tau_\tau)(1-\gamma)(1-\lambda)s\delta\phi^* b_l}=\frac{\gamma}{(1-\tau_\tau)}.$$

If $\tau_\tau = 1$ when $s = 1$, then RHS of eq. (25) becomes infinity, implying that eq. (25) does not hold as LHS of eq. (25) is not equal to infinity when $s = 1$. Moreover, when $s = 1$, τ_τ cannot be greater than 1. If $\tau_\tau > 1$, then the LHS of eq. (25) is negative while the RHS is positive, implying that eq. (25) does not hold. Thus, the only possible value of τ_τ when $s = 1$ must be less than one.

Moreover, by defining $x = p_L\big(1-\delta(1-s)\big)+p_H\delta(1-s)$, eq. (26) can be rewritten as

$$\tau_\tau=\frac{[(1-\lambda)(1-\gamma)sM_2]\gamma\frac{\partial M_1}{\partial s}+M_1(1-\gamma)^2(1-\lambda)\left(M_2+s\frac{\partial M_2}{\partial s}\right)}{1+[(1-\lambda)(1-\gamma)sM_2]\gamma\frac{\partial M_1}{\partial s}+M_1(1-\gamma)^2(1-\lambda)\left(M_2+s\frac{\partial M_2}{\partial s}\right)}$$

$$\frac{(1-\gamma)}{1+\dfrac{1}{[(1-\lambda)sM_2]\gamma\frac{\partial M_1}{\partial s}+M_1(1-\gamma)(1-\lambda)\left(M_2+s\frac{\partial M_2}{\partial s}\right)}}$$

where

$$M_1=\frac{\lambda p_H^2+(1-\lambda)p_L\big[p_L\big(1-\delta(1-s)\big)+p_H\delta(1-s)\big]}{\{\lambda p_H^2+(1-\lambda)\big[p_L\big(1-\delta(1-s_t)\big)+p_H\delta(1-s_t)\big]^2\}^{0.5}}$$

and

$$M_2=\frac{(p_L-p_H)[1-\delta(1-s)]x}{\lambda p_H^2+(1-\lambda)x^2}.$$

When $s = 0$,

$$\tau_\tau=\frac{1-\gamma}{1+\dfrac{1}{M_1(1-\gamma)^2(1-\lambda)M_2}}.$$

Since $M_1 > 0$ and $M_2 > 0$ for any $s \in [0,1]$, it is clear that $\tau_\tau < 1-\gamma$ when $s = 0$.