WHAT DO INFORMATION FRICTIONS DO?*

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Abstract

Numerous researchers have incorporated labor or credit market frictions within simple neoclassical models to (i) facilitate quick departures from the Arrow-Debreu world, thereby opening up the role for institutions, (ii) inject some realism into their models, and (iii) explain cross country differences in output and employment. We present an overlapping generations model with production in which a labor market friction (moral hazard) coexists along with a credit market friction (costly state verification). The simultaneous presence and interaction of these two frictions is studied. We show that credit frictions have a multiplier effect on economic activity, by directly affecting investment and indirectly through the unemployment rate. The labor market friction, on the other hand, affects unemployment in the short- and long-run but has only a short-run effect on capital accumulation.

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1 Introduction

This paper studies multiple informational frictions in a neoclassical growth model with the objective of understanding how credit and labor market frictions interact to contribute to persistent involuntary unemployment and relative income gaps across nations. To that end, we analyze an overlapping generations economy with production in which a labor market friction (moral hazard) coexists with a credit market friction (costly state verification). The simultaneous presence and interaction of these two frictions is studied. An increase in the severity of credit market distortions decreases long-run employment, while a worsening of the labor market friction results in lower income per capita than would obtain otherwise.

Researchers have incorporated labor and credit market imperfections within simple neoclassical models principally to facilitate quick departures from the Arrow-Debreu world thereby opening up the role for institutions and injecting a healthy dose of realism into their models. For instance, the role of credit frictions in growth, development, and business cycles has been highlighted by a number of contributions including Bernanke and Gertler (1989), Bencivenga and Smith (1993), Boyd and Smith (1997, 1998), Huybens and Smith (1998), Carlstrom and Fuerst (1997) and Azariadis and Chakraborty (1998). Concurrently, another branch of the literature, as exemplified by Smith (1989, 1995), Bencivenga and Smith (1997) and Jullien and Picard (1998), has discussed how labor market frictions affect aggregate outcomes. Almost the entire existing literature, however, treats these frictions in isolation. Yet there is good reason to believe that credit and labor markets are tightly interlinked and that effects in one market often spill over into the other, either dampening or amplifying these effects. This paper aims to demonstrate that the "value added" to considering these frictions jointly is substantial.

The empirical relevance of these aforementioned frictions, not only for poorer countries but also the richer ones, is well-documented.[1] For instance, Jappelli (1990) provides systematic evidence on widespread credit rationing in a country as financially evolved as the US. Evans and Jovanovic (1989) and Blanchflower and Oswald (1998) note that the probability of self-employment depends positively upon whether the individual ever received an inheritance indicating the imperfectness of capital markets. About a fifth of respondents in a 1987 UK survey on the self-employed rated *where* to get finance as their biggest difficulty (Blanchflower and Oswald, 1998). In recent years, tight credit market conditions in Japan has partially been blamed for the

[1] Banerjee (2001) provides a comprehensive survey of micro-econometric evidence from developing countries. Wurgler (2000) finds developed financial markets are associated with a better allocation of capital. In fact, "although financially developed countries might not invest at a higher level, they do seem to allocate their investment better."

lack of employment growth there.[2] Rajan and Zingales (1998) use industry-level data to show how greater credit frictions in Europe, compared to the US, have subdued growth in industries that are more dependent on external finance. Similarly, labor market frictions have in recent years, received ample attention from commentators analyzing the marked rise of European unemployment over the past three decades (see Rogerson, 2000, for comprehensive and up-to-date evidence).

There is some persuasive evidence that credit market conditions may have strong effects on employment.[3,4] Consider the fact that nearly 40% of jobs in the U.S., for instance, are held in small firms (those with less than 100 employees) while 58.1% of private sector workers are in firms with less than 500 employees (BLS, 2000). Small businesses are also the primary source of *new* jobs in the U.S. economy. "From 1990 to 1995, businesses with fewer than 500 employees accounted for 76.5 percent of net new jobs. But small businesses have a very high turnover rate compared to large businesses. Over 13 percent of U.S. jobs in 1995 were in firms that did not exist before 1990 and over 12 percent of jobs in 1990 were in firms that had ceased to exist by 1995" (Berkowitz and White, 2002). These small firms, the ones most likely to face the greatest difficulties in raising external finance, therefore contribute significantly to job creation and destruction in the U.S. In the case of Europe, Acemoglu (2000) notes how the fraction of employment in the most credit-dependent industries has been lower there than in the United States.[5]

Our analysis bridges the gap in the literatures on credit and labor market frictions. On the credit side, we adopt Townsend (1979) and Gale and Hellwig's (1985) costly state verification

[2] The IMF in its 1999 report on Japan noted: "The drop of business investment over the past two years has been particularly severe. ...reduced expectations of long-term growth encouraged firms to cut-back plans for capital accumulation. Limits on the availability of bank credit also seem to have been a negative factor...expectations of future earnings have been undermined by a rising unemployment rate and by prospects for further increases in the period ahead as a number of major corporations have announced employment reduction plans."

[3] There is a long tradition in development economics that studies, in partial equilibrium settings, "interlinked rural markets", labor markets with or without bonded labor that are operated under the supervision of usurious (monopolistic) money lenders. See Basu (2000) for an extended discussion.

[4] The simple correlation between the unemployment rate in 20 OECD countries and the net interest margin (a measure of credit market efficiency, it is the the accounting value of a bank's net interest revenue as a share of its total assets) in those countries is about 0.37. The unemployment data are standardized averages from 1991-97 from the OECD, and the net interest margin data are time-averaged over the same period from the Beck, Demirgkuc-Kunt and Levine (1999) dataset. Note that net interest data likely understate true costs of credit because they are computed *ex post*, net of losses on non-performing loans.

[5] Economic historians too have touched upon similar issues. Williamson (1984) notes that during the British Industrial Revolution, certain industries like construction contributed heavily to GDP (and employment) and yet were severely credit constrained by the high interest rates at the time. Hamilton (1999) argues that white landowners in the South around the time of the Civil War were often so credit strapped that they could not pay their black slaves any cash wages, and this affected the employment situation and well-being of many black families at the time.

approach to provide a clear channel through which borrowing constraints and related distortions affects investment decisions. On the labor market side, we adapt the Shapiro and Stiglitz (1984) moral hazard and efficiency wages framework.[6] We prefer this over an adverse selection model partly because the empirical relevance of the efficiency wage model is fairly well-documented (Huang et al, 1998), but also because it facilitates a rich and tractable analysis.

In our model, workers suffer disutility costs of working and of exerting effort. Firms can perfectly observe the former but receive a noisy signal about how averse workers are to exert full effort. Consequently, they hire only those who have 'low enough' disutility costs of working, while others remain *involuntarily* unemployed. Incentive compatible wage payments are also tailored to elicit full effort from the employed. Not surprisingly, the higher is the wage rate, the less is a worker's incentive to shirk and hence, lower is the unemployment rate. In this scenario, credit frictions lower wages by hurting capital accumulation, and this tends to exacerbate unemployment problems.

Labor frictions, at the same time, resonate in the credit market. Since investment projects are indivisible and subject to idiosyncratic shocks that are not costlessly observed by lenders, agency costs determine how many potential entrepreneurs obtain loans and produce capital. More severe incentive problems in the labor market lower employment, and thus, squeeze the pool of potential capitalists. Additionally, higher unemployment lowers the supply of loanable funds. On account of both, less investment and capital production per capita is undertaken than would result in well performing labor markets.

This *bi-directional* interaction between the two markets is an important new contribution to the literature. Three papers that present an unidirectional connection and relate most closely to our work are Betts and Bhattacharya (1998), Acemoglu (2000) and Wasmer and Weil (2002). Betts and Bhattacharya (1998) study how adverse selection problems in the labor market in the presence of credit market frictions can lead to complex dynamics, cycles and development traps. However, in their setup, by virtue of their assumption that all capitalists remain unemployed and receive a constant "home production output", wage rates in the labor market really have no direct effect on the credit market, except through the supply of funds. In contrast, in the current setup, wages are used as collateral by employed capitalists, and that helps determine the credit terms and loan rates they receive on the credit market. Wasmer and Weil (2002) model specificity in credit relationships, and assume that credit to potential loan-seekers is rationed due to search

[6] The moral hazard and efficiency wage hypothesis is at the center of many papers analyzing labor market dynamics in the general equilibrium tradition, notably, Danthine and Donaldson (1990), Kahn and Mookherjee (1987), Coimbra (1996), Gomme (1999), among others.

frictions. Similarly, search frictions in the labor market produce equilibrium unemployment. In contrast, our analysis focuses on credit rationing and unemployment as phenomena arising out of informational asymmetries. Acemoglu (2000) uses a simple model in which Europe and the U.S. are identical to begin with except that credit market frictions are more widespread in the former. He goes on to consider the response of these two economies to a common shock, the arrival of a new set of technologies. The upshot is that the economy with better credit markets will respond to the arrival of new technologies without an increase in unemployment. In contrast, in Europe with worse credit markets, the change in technologies can have a persistent adverse effect on unemployment because, in the absence of efficient credit markets, the agents who need funds to start up new projects cannot borrow the necessary funds.[7]

The rest of the paper is organized as follows. In the next section, we outline the model environment, the preferences, and technology. In Section 3, we study the efficiency wage contracts, and in Section 4, we spell out the details of the credit market contract under the costly state verification problem. The next section contains the general dynamic equilibrium determination of the capital stock, the loan rates, and the wage rates. It also includes our main interaction result, the one connecting the severity of the credit market friction with the level of unemployment. In Section 6, we undertake a comparative study of four models that are nested within our two-friction model. Section 7 contains a discussion of our main result, some concluding remarks, and some ideas for future research.

2 Environment

We analyze a production economy inhabited by an infinite sequence of two-period lived overlapping generations, plus an initial old generation. At each date, $t = 1, 2, 3...$, a new generation is born, consisting of a continuum of agents with mass 1. Thus, the measure of total population at any date t is 2.

All agents are *ex ante* identical and endowed with a unit labor time in youth. When young, an agent may find work or remain unemployed. Some of the employed workers subsequently obtain a production opportunity that enables them to produce capital and become capitalists. Only the initial old generation is endowed with an aggregate stock of $K_1 > 0$ units of capital.

Following factor market trade and production, at the end of a period, young agents meet

[7] Ghatak, Morelli, and Sjostrom (2002) study an interesting environment in which the extent of credit rationing and the type of loan contracts offered, depends on the wage rates in the labor market, via an occupational-choice decision.

again in the credit market. As discussed below, at this time young capitalists seek external financing for their projects from young workers. At the start of the following period, returns are realized (in units of new capital). The old capitalists (firms) then hire labor and capital to produce the final good, and any loans taken by capitalists for external financing of investment projects are repaid.

In each period, there is a single final perishable good in the economy. The final good may be consumed or invested in the production of future capital. This good is produced by firms (old capitalists) who have access to a constant returns technology that combines capital, K, with effective labor, $(1-\upsilon)L$, to produce output $F(K,(1-\upsilon)L)$. Here υ is the fraction of employees that exert no effort or shirk (see below), and L is the total number of employees. To foreshadow, in equilibrium, firms will write efficiency wage contracts that optimally set $\upsilon = 0$, that is, they employ only non-shirkers.

Let $k_t \equiv K_t/\left((1-\upsilon)L_t\right)$ denote the capital to effective-labor ratio, and $f(k_t) \equiv F(k_t, 1)$, denote the associated intensive production function where f satisfies $f(0) = 0$, $f' > 0 > f''$, and standard Inada conditions. For much of what we do below, we will assume a specific Cobb-Douglas form for f,

$$f(k) = Ak^{\alpha}, \quad A > 0, \quad \alpha \in (0,1). \tag{1}$$

Standard factor pricing relationships imply that the gross real return to capital is given by

$$\rho_t = f'(k_t) = \alpha A k_t^{\alpha-1}, \tag{2}$$

and the wage rate by

$$\omega_t = \omega(k_t) \equiv f(k_t) - k_t f'(k_t) = (1-\alpha)Ak_t^{\alpha}. \tag{3}$$

The capital investment technology (project) to which capitalists have sole access is an indivisible risky linear stochastic technology in that $q > 0$ units of the final good invested in a project at date t yield zq units of capital at $t+1$, where z is an *i.i.d.* (across capitalists and dates) random variable, which is realized at $t+1$. We let G denote the probability distribution of z, and assume that G has a differentiable density function g with finite support $[0, \bar{z}]$, $\bar{z} < \infty$. We denote by $\hat{z}$ the mean of z.

The amount of capital actually produced by a project is private information to the project owner. Any other agent can perfectly witness the return on that project only by incurring a *fixed* cost of $\gamma > 0$ units of capital.[8] This informational asymmetry embedded in the capital

[8] We follow Bernanke and Gertler (1989) and Boyd and Smith (1998) in using this standard assumption.

investment technology is the source of credit market frictions. Finally, we assume that once the new capital produced by a project between t and $t+1$ has been used in the production of final goods at $t+1$, it depreciates completely.

3 Labor Market Contracts

All agents are risk-neutral and care only about their second period consumption (c_2). Specifically, we assume $U(c_2) = \beta c_2$, gross of any work-related disutilities (see below). Let S_t denote an agent's saving when young, and let R^S_{t+1} denote the gross return to saving. For future use, note that $c_{2,t+1} = R^S_{t+1} S_t$ and indirect lifetime utility is simply $\beta R^S_{t+1} S_t$, again gross of work-related disutilities.

The basic formulation of the labor market closely follows Coimbra (1999) and Jullien and Picard (1998). Any worker can either work the entire one unit of time or shirk completely. Workers can choose the level of effort e, where $e = \{0, 1\}$. Let $v > 0$ and $a > 0$ represent disutilities from being employed and from actually working. We assume that v is identical for all young agents but that a differs. In particular, $a \sim F(a)$ with support $[\underline{a}, \infty]$ and $\underline{a} > 0$. Utility from work with full effort ($e = 1$) is therefore given by $\beta c_2 - (v + a)$, from shirking ($e = 0$) by $\beta c_2 - v$, and by $\beta c_2 \geq 0$ if unemployed.

Firms observe a but not a worker's effort. However, they do receive an imperfect verifiable binary signal, that takes a high or a low value, regarding how much effort a worker has put in. We let θ denote the conditional probability that the signal takes on a high value even when effort is zero.

As Jullien and Picard (1998) show, firms offer a wage contract $\{\omega_1(a), \omega_0(a)\} \in \Re^2_+$ to each worker of type a, where $\omega_1(a)$ is the wage for a high value of the signal and $\omega_0(a)$ is the wage for a low value. Firms want all workers to exert full effort. Therefore, the wage contract is incentive compatible as long as

$$\begin{aligned} \beta R^S_{t+1} \omega_1(a) - v - a &> [\theta w_1(a) + (1-\theta)\omega_0(a)] \beta R^S_{t+1} - v \\ \Leftrightarrow \beta R^S_{t+1} (1-\theta)[\omega_1(a) - \omega_0(a)] &\geq a \end{aligned} \tag{4}$$

Since unemployed workers earn zero income, it is rational for a type a worker to sign such a contract if

$$\begin{aligned} &\beta R^S_{t+1} \omega_1(a) - v - a \geq 0 \\ &\Leftrightarrow \beta R^S_{t+1} \omega_1(a) \geq (v + a). \end{aligned} \tag{5}$$

This is the worker's participation constraint.

Assume without loss of generality that $\omega_0(a) = 0$. Then, all unemployment is involuntary, if (4) implies (5) and the latter is not binding. A sufficient condition for this is

Assumption 1

$$v \leq \frac{\underline{a}\theta}{(1-\theta)} > 0,$$

which we shall henceforth maintain.

Note that since R^S_{t+1} is endogenous, the worker's participation constraint (5) is endogenously determined too. Agents do not consume in the first period of their lives so that workers' savings equal their wage income ω_t. The incentive constraint (4) binds and therefore,

$$\hat{a}_t = \beta(1-\theta)\omega_t R^s_{t+1}$$

holds. Since full effort by any worker produces the same output, each employed worker must get the same wage, irrespective of their disutility from work, a. *Ceteris paribus*, an increase in θ (noisiness of the output signal) reduces employment; similarly, an increase in the wage rate is associated with reduced unemployment.

Proposition 1 *(Jullien and Picard, 1998) An optimal labor contract is a triple $\{\omega_0(a_t), \omega_1(a_t), \hat{a}_t\}$ such that (i) $\omega_0(a_t) = 0$ for all $a_t > \hat{a}_t$, (ii) $\omega_1(a_t) = \omega_t$ (see eq. 3) for all $a_t \leq \hat{a}_t$, and, (iii) all workers with disutility cost of working less than $\hat{a}_t$ are employed and exert full effort.*

It follows that total employment is

$$L_t = F(\hat{a}_t) = F\left(\beta(1-\theta)\omega_t R^s_{t+1}\right), \tag{6}$$

while for an aggregate capital stock of K_t, the aggregate capital-labor ratio is given by

$$k_t \equiv \frac{K_t}{L_t} = \frac{K_t}{F(\hat{a}_t)}. \tag{7}$$

Similarly, the unemployment rate in the economy is defined by

$$u_t \equiv 1 - F(\hat{a}_t), \tag{8}$$

and, with a slight abuse of terminology, we shall use the capital stock per young agent to denote the *per-capita* capital stock:

$$\widetilde{k}_t \equiv K_t. \tag{9}$$

4 Credit Markets

We are now prepared to describe the activities of agents in the credit market. After labor market outcomes are realized and all compensation received, workers are allocated a production opportunity with probability $\varphi \in (0, 1)$ as in Khan (2001). This opportunity enables a young worker to become a capitalist and produce capital using the aforementioned capital-production technology. By the law of large number, a φ fraction of the workers receive this opportunity in any period.

Under the terms of the labor contracts discussed above, each worker receives a real income ω_t when young. A measure of workers L_t given by (6) find jobs, the rest remain unemployed and receive zero lifetime utility. Among these workers, φL_t have the potential to become capitalists, the others simply invest their savings in alternative means.

Following Williamson (1986), we assume without any loss of generality that all lending is intermediated. In other words, workers who do not receive the capital production opportunity simply deposit their savings with an intermediary who pools these deposits and makes loans on their behalf. In addition, following Diamond (1984), intermediaries perform the role of delegated monitors, verifying project returns as per the terms of loan contracts. We assume that any lender may establish an intermediary. In equilibrium, with unrestricted entry into the market for intermediation services, all intermediaries must offer a common competitively determined deposit return, r_{t+1}, must hold perfectly diversified loan and deposit portfolios, and must earn zero profits. In this context, it is important to note that project returns are *i.i.d.* across capitalists, that there exists a continuum of capitalists, and that there is no aggregate randomness. Consequently, an intermediary with a perfectly diversified loan portfolio earns a non-stochastic return on its assets and need not be monitored by its depositors.

4.1 Loan Contracts

The capital investment technology (project) to which capitalists have sole access, is an indivisible technology that can only be operated at the scale q.[9] We assume that *all* capitalists need some amount of external financing to operate their individual projects. Equivalently, we assume that

Assumption 2

$$q > \omega_t$$

[9] Boyd and Smith (1998) discuss how the determination of the equilibrium capital stock is unaffected by abandoning the assumption that project scale is fixed at q.

holds at all dates. All capitalists therefore need external financing of the amount

$$b_t = q - \omega_t > 0.$$

Potential borrowers, wishing to obtain external funding, announce loan contracts that may be accepted or rejected by lenders (banks). Borrowers whose contracts are accepted receive external funding of the amount b after which they operate their projects.

Under this costly state verification setup and deterministic monitoring, Gale and Hellwig (1985) and Williamson (1986) show that optimal loan contracts take a simple form. In particular, the state space $[0, \bar{z}]$ is divided into two subsets A_t and B_t. For all realizations of $z \in A_t$, intermediaries verify project returns for sure. But if $z \in B_t \equiv [0, \bar{z}] - A_t$, no verification occurs. Let $R_t(z)$ denote the promised real payment per unit borrowed for all $z \in A_t$. Since no verification occurs on B_t, incentive compatible payments would have to be independent of realizations of z. Let x_t denote this uncontingent payment (per unit borrowed) for all $z \in B_t$.

Intermediaries take the return to be paid on deposits between t and $t+1$, r_{t+1}, as given and act as if there is a perfectly elastic demand for deposits at this rate. Hence, they agree to the terms of such a loan contract only if the expected return on lending is at least as great as r_{t+1}. Formally, this participation constraint can be written as

$$\int_{A_t} \left[R_t(z) b_t - \rho_{t+1}\gamma\right] g(z)dz + x_t b_t \int_{B_t} g(z)dz \geq r_{t+1} b_t, \tag{10}$$

where $\rho_{t+1}\gamma \int_{A_t} g(z)dz$ is the real expected monitoring cost. In addition, all contracts must be incentive compatible, that is,

$$R_t(z) \leq x_t \text{ for } z \in A_t \tag{11}$$

must hold. Finally, it must be feasible for borrowers to repay (limited liability),

$$R_t(z) \leq \left[\frac{\rho_{t+1} z q}{b_t}\right] \text{ for } z \in A_t \tag{12}$$

and

$$x_t \leq \inf_{z \in B_t} \left[\frac{\rho_{t+1} z q}{b_t}\right]. \tag{13}$$

Potential capitalists simply maximize their own expected utility by choosing the contractual obligations optimally subject to the constraints (10)-(13). The solution to this problem is a standard debt contract. When the capitalist realizes a return $z \in B_t$, he pays x_t (principal plus interest) to the lender. When $z \in A_t$, he defaults; in this case, the intermediary monitors the project and retains the entire proceeds (rental income from whatever capital is produced) net of monitoring costs.[10]

Proposition 2 *(Williamson, 1986, 1987a) The optimal loan contract satisfies*

$$R_t(z) = \left[\frac{\rho_{t+1} q}{b_t}\right] z \quad \textit{for } z \in A_t,$$

$$A_t = [0, \frac{x_t b_t}{q\rho_{t+1}}),$$

and

$$r_{t+1} = \int\limits_{A_t} \left[R_t(z) - \frac{\rho_{t+1}\gamma}{b_t}\right] g(z)dz + x_t \int\limits_{B_t} g(z)dz.$$

Using Proposition 2, it is also easy to show the following:

$$r_{t+1} = x_t - \left(\frac{\rho_{t+1}\gamma}{b_t}\right) G\left(\frac{x_t b_t}{q\rho_{t+1}}\right) - \left(\frac{\rho_{t+1} q}{b_t}\right) \int_0^{\frac{x_t b_t}{q\rho_{t+1}}} G(z)dz \equiv \Phi\left[x_t; \frac{b_t}{\rho_{t+1}}\right],$$

where the function Φ gives the expected return to the lender as a function of the gross loan rate, x_t, the amount borrowed, b_t, and the future relative price of capital, ρ_{t+1}. Following Williamson (1986, 1987), we impose the following assumptions:

Assumption 3

$$g(z) + \left(\frac{\gamma}{q}\right) g'(z) \geq 0 \textit{ for } z \in [0, \bar{z}]$$

and

Assumption 4

$$\Phi_1\left[0, \left(\frac{b_t}{\rho_{t+1}}\right)\right] \equiv 1 - \frac{\gamma}{q} g(0) - G(0) > 0.$$

Assumption 3 ensures the concavity of Φ, that is, $\Phi_{11} < 0$. In addition, if assumption 4 holds, Φ is inverse U- shaped. Hence there will be a unique x_t depending upon b_t/ρ_{t+1} which maximizes the expected return to a lender. We denote this value by $\hat{x}\left(\frac{b_t}{\rho_{t+1}}\right)$ where

$$\Phi_1\left[\hat{x}\left(\frac{b_t}{\rho_{t+1}}\right), \left(\frac{b_t}{\rho_{t+1}}\right)\right] \equiv 1 - \left(\frac{\gamma}{q}\right) g\left[\hat{x}\left(\frac{b_t}{\rho_{t+1}}\right)\frac{b_t}{q\rho_{t+1}}\right] - G\left[\hat{x}\left(\frac{b_t}{\rho_{t+1}}\right)\frac{b_t}{q\rho_{t+1}}\right] = 0 \qquad (14)$$

[10] Such monitoring or auditing costs can be fairly substantial even in developed countries. For example, Del Boca and Lusardi (1998) quote a Bank of Italy estimate that it took 5.5 years on average for an Italian bank to repossess the collateral.

Equation (14) and assumption 3 imply that

$$\hat{x}\left(\frac{b_t}{\rho_{t+1}}\right)\frac{b_t}{q\rho_{t+1}} \equiv \delta \tag{15}$$

where $\delta > 0$ is a constant satisfying

$$1 - (\gamma/q)\, g(\delta) - G(\delta) \equiv 0.$$

The object δ has a straightforward implication: the set A_t is now defined by $z \in [0, \delta)$. That is, when all potential borrowers are offering the interest rate that maximizes a prospective lender's expected rate of return, δ is the critical project return for which a borrower's project income exactly covers loan principal plus interest.

4.2 Credit Rationing

In the environment specified above, it is quite possible to have an unsatisfied demand for credit as originally noted by Gale and Hellwig (1985) and Williamson (1986, 1987a). If all capitalists want to run their projects at any date t then the total demand for credit (net of internal finance) is just $\varphi(q - \omega_t)L_t$. Aggregate supply of funds comes from the saving of all employed workers which is $(1 - \varphi)\omega_t L_t$. Then a necessary condition for credit rationing to hold for all t is

$$(1 - \varphi)\omega_t L_t < \varphi\,(q - \omega_t)\, L_t \Leftrightarrow \varphi q > \omega_t \tag{16}$$

If (16) is satisfied, there will be credit rationing in equilibrium and

$$x_t \equiv \hat{x}\left(\frac{b_t}{\rho_{t+1}}\right)$$

must hold. This implies that under credit rationing, all potential borrowers are offering the interest rate that maximizes a prospective lender's expected rate of return. No borrower can therefore obtain credit by changing the interest rate and other loan terms without reducing the expected return for all lenders. In this setting, some borrowers must remain unsatisfied, or in other words, credit rationing will obtain in equilibrium. Below, we focus on economies where rationing occurs at all dates.

The following lemma summarizes information about the payoffs to lenders and all funded borrowers.

Lemma 1 *(Boyd and Smith, 1998) Suppose*

$$\hat{z} > \left(\frac{\gamma}{q}\right) G(\delta)$$

holds. Then ***(a)*** *the expected return on deposits that the intermediary offers,* r_{t+1}*, is given by*

$$r_{t+1} = \psi \frac{\rho_{t+1}}{b_t} \tag{17}$$

where

$$\psi \equiv q \left[\delta - \left(\frac{\gamma}{q} \right) G(\delta) - \int_0^{\delta} G(z) dz \right],$$

and ***(b)*** *the expected utility of a funded borrower under credit rationing is given by*

$$\rho_{t+1} q \phi - r_{t+1} b_t,$$

where

$$\phi \equiv \hat{z} - \left(\frac{\gamma}{q} \right) G(\delta).$$

The proof of this lemma follows directly from the arguments in Boyd and Smith (1997, 1998). It must also be the case that any potential capitalist actually prefers borrowing and operating his project to simply depositing his income with the intermediary. Boyd and Smith (1998) prove that a sufficient condition for all capitalists to operate their projects using external finance is

Assumption 5

$$(1 - \alpha) \phi q \geq \psi.$$

5 General Equilibrium

We first analyze the markets for credit and capital in general equilibrium. Equilibrium in the credit market under credit rationing implies that only a fraction $\mu_t < 1$ of all capitalists get external funding at each date t. Each funded borrower borrows an amount b_t. Therefore, the total volume of loans granted is $\mu_t \varphi L_t b_t$. The total supply of savings is the sum of the wage incomes of employed workers who did not receive a capital production opportunity. These are the natural lenders of our economy. Additionally, unfunded capitalists also deposit their funds with an intermediary and, in effect, become lenders. Hence, the total supply of loanable funds is given by

$$(1 - \varphi) L_t \omega_t + \varphi (1 - \mu_t) L_t \omega_t. \tag{18}$$

Equality between the "sources" and "uses" of funds requires that

$$\mu_t \varphi L_t b_t = (1 - \varphi) L_t \omega_t + \varphi (1 - \mu_t) L_t \omega_t \tag{19}$$

hold for all t, which simplifies to

$$\mu_t \varphi q = \omega_t. \tag{20}$$

It follows from (16) that $\mu_t < 1$.

As discussed earlier, there is no aggregate randomness in this economy. Consequently, the $t+1$ capital stock is $(\mu_t \varphi L_t)\, \hat{z} q$ less the amount of capital spent on monitoring. This monitoring cost is given by $(\mu_t \varphi L_t)\, \gamma G \left[x_t b_t / (\rho_{t+1} q) \right] \equiv (\mu_t \varphi L_t) \gamma G(\delta)$. Thus, the equilibrium aggregate capital stock at $t+1$ is given by

$$K_{t+1} = \mu_t \varphi L_t \left[\hat{z} q - \gamma G(\delta) \right] \equiv \mu_t \varphi \phi q L_t \tag{21}$$

Now, using (20), and noting that $L_t = \digamma\left(\hat{a}_t\right)$, we can eliminate μ_t to obtain

$$K_{t+1} = \phi \omega_t \digamma\left(\hat{a}_t\right) \tag{22}$$

It follows then (using (7)) that

$$k_{t+1} \equiv \frac{K_{t+1}}{L_{t+1}} = \frac{\phi \omega(k_t) \digamma\left(\hat{a}_t\right)}{\digamma\left(\hat{a}_{t+1}\right)} = \phi \omega(k_t) \frac{\digamma\left(\hat{a}_t\right)}{\digamma\left(\hat{a}_{t+1}\right)} \tag{23}$$

5.1 Stationary and Non-Stationary Equilibria

Recall from (6) that

$$\digamma\left(\hat{a}_t\right) = \digamma\left(\beta(1-\theta)\omega(k_t) R^s_{t+1}\right)$$

In equilibrium, the return to saving $\left(R^s_{t+1}\right)$ for a employed worker must equal r_{t+1} (the return on deposits that the bank promises) which is computed using (17). Then, the equilibrium capital-labor ratio [using (23)] is given by:

$$k_{t+1} \equiv \phi \omega(k_t) \frac{\digamma\left(\hat{a}_t\right)}{\digamma\left(\hat{a}_{t+1}\right)} \tag{24}$$

$$= \phi \omega(k_t) \frac{\digamma\left[\beta(1-\theta)\omega(k_t) r(k_{t+1}, k_t)\right]}{\digamma\left[\beta(1-\theta)\omega(k_{t+1}) r(k_{t+2}, k_{t+1})\right]} \tag{25}$$

Equation (25) describes the equilibrium law of motion for k_t when credit is rationed at all dates.[11] Given an initial value for k_1, equation (25) describes the subsequent evolution of any potentially valid equilibrium sequence $\{k_t\}_{t=2}^{\infty}$; from such a sequence, it is easy to compute the

[11] In the lucid prose of Azariadis (1993), "It would not be a gross misrepresentation to say that the business of modern macroeconomics amounts to "complicating" ..the dynamical system [from the Diamond model] and exploring what happens as new features are added". To foreshadow, our results indicate that adding both a labor and a credit market friction onto the benchmark Diamond model has strong short-run implications but not necessarily dramatic long-run implications.

equilibrium sequences for $\{\mu_t\}_{t=1}^{\infty}$, $\{\hat{a}_t\}_{t=1}^{\infty}$, $\{u_t\}_{t=1}^{\infty}$ etc. Stationary equilibria are time-invariant solutions to (25) and are summarized by

$$k = \phi\omega(k) \tag{26}$$

It will, however, be more convenient to express the dynamics of (25) as a two-dimensional dynamical system:

$$\begin{aligned} k_{t+1} &= \phi\omega(k_t)\frac{F(\hat{a}_t)}{F(\hat{a}_{t+1})}, && (27)\\ \hat{a}_t &= \beta(1-\theta)\omega(k_t)r(k_t,k_{t+1}). && (28) \end{aligned}$$

Here, using (17), we have

$$r(k_t,k_{t+1}) = \frac{\psi f'(k_{t+1})}{q-\omega(k_t)}.$$

Under the assumption of Cobb-Douglas technology, as in (1), it is easy to show that

$$\hat{a}_t = \hat{\eta}\left[\frac{(1-\alpha)Ak_t^{\alpha}}{q-(1-\alpha)Ak_t^{\alpha}}\right]k_{t+1}^{\alpha-1} \tag{29}$$

where

$$\hat{\eta} \equiv \alpha\beta\psi(1-\theta)A.$$

Rewriting (29), we get

$$k_{t+1} = \eta G(k_t)\hat{a}_t^{-1/(1-\alpha)} \tag{30}$$

where

$$\eta \equiv \hat{\eta}^{1/(1-\alpha)},\ G(k) \equiv \left[\frac{(1-\alpha)Ak^{\alpha}}{q-(1-\alpha)Ak^{\alpha}}\right]^{1/(1-\alpha)}.$$

Now using (27) in (30), we get

$$\begin{aligned} F(\hat{a}_{t+1}) &= \phi(1-\alpha)Ak_t^{\alpha}\frac{F(\hat{a}_t)}{k_{t+1}}\\ &= \sigma H(k_t)F(\hat{a}_t)\hat{a}_t^{1/(1-\alpha)} && (31) \end{aligned}$$

where

$$\sigma \equiv \phi/\eta,\ H(k) \equiv \frac{(1-\alpha)Ak^{\alpha}}{G(k)}.$$

Thus, the steady-states $(k^*, \hat{a}^*)$ solve the two equations:

$$\begin{aligned} k^* &= \eta G(k^*)(\hat{a}^*)^{-1/(1-\alpha)},\\ F(\hat{a}^*) &= \sigma H(k^*)F(\hat{a}^*)(\hat{a}^*)^{1/(1-\alpha)}, \end{aligned}$$

which can be further simplified to obtain

$$\begin{aligned} k^* &= [(1-\alpha)\phi A]^{1/(1-\alpha)}, \\ \hat{a}^* &= \alpha\beta\psi(1-\theta)A\left[\frac{G(k^*)}{k^*}\right]^{1-\alpha}. \end{aligned}$$

Proposition 3 *The non-trivial steady-state $(k^*, \hat{a}^*)$ is a saddle.*

Proof. See Appendix A. ■

Proposition 3 suggests that the unique equilibrium path of $\{k_t, a_t\}$ asymptotically converges to the stationary equilibrium $(k^*, \hat{a}^*)$. Given the initial aggregate capital stock, K_1, and perfect foresight, the initial $\hat{a}_1$ is determined such that $(k_1, \hat{a}_1)$, where $k_1 \equiv K_1/F(\hat{a}_1)$, places the economy on the stable manifold approaching this stationary equilibrium.

5.2 Comparative Statics

We quickly undertake a bunch of comparative statics exercises to illustrate the cross effects of one friction on the other. The starting point of our analysis is the expression for the steady state capital-labor ratio derived under the assumption of Cobb-Douglas technology and using (26):

$$k^* = [(1-\alpha)\phi A]^{\frac{1}{1-\alpha}} = [(1-\alpha)A]^{\frac{1}{1-\alpha}}\left[\hat{z} - \left(\frac{\gamma}{q}\right)G(\delta)\right]^{\frac{1}{1-\alpha}} \tag{32}$$

It is evident that $\partial k^*/\partial\gamma < 0$ and $\partial k^*/\partial q > 0$.

To investigate the effects of changing parameters, such as γ, on the labor market, recall from (29) that

$$\hat{a}^* = \alpha\beta\psi(1-\theta)A\left[\frac{(1-\alpha)A(k^*)^\alpha}{q-(1-\alpha)A(k^*)^\alpha}\right](k^*)^{\alpha-1}$$

or using the definition of ψ, we have (after simplifying)

$$\hat{a}^* = \alpha(1-\alpha)\beta q(1-\theta)A^2\left[\delta - \left(\frac{\gamma}{q}\right)G(\delta) - \int_0^\delta G(z)dz\right]\left[\frac{(k^*)^{2\alpha-1}}{q-(1-\alpha)A(k^*)^\alpha}\right] \tag{33}$$

The fact that the labor market friction parameter, θ, does not contribute to the determination of the steady state capital-labor ratio (see (32)) is noteworthy. It follows (from (20)) that the labor friction does not affect μ, the fraction of capitalists who receive funding. But this is not to say that the labor market friction has no effect on any aggregate variables. From (33), it is apparent that $\partial\hat{a}^*/\partial\theta < 0$ implying that a worsening of the labor market friction reduces equilibrium employment. Consequently, it follows from (22) that the aggregate capital stock (and the *per capita* capital stock) falls when the severity of the labor friction increases. Finally, note that the labor friction parameter, θ, definitely affects *short-run* employment, as is evident from (29).

The upshot of the previous discussion is that moral hazard in the labor market has short-run effects on the capital-labor ratio and employment, but no effect on the long-run factor intensity. In contrast, credit market frictions have both short- and long-run effects. This is easily seen by considering the effect of increasing the monitoring cost, γ. An increase in γ decreases the level of long-run employment so that credit frictions spill over into the labor market, exacerbating unemployment problems. The following proposition notes this.

Proposition 4 *An increase in the severity of the credit market friction lowers steady-state employment, that is,*

$$\frac{\partial \hat{a}^*}{\partial \gamma} < 0.$$

Proof. See Appendix B. ■

An increase in the monitoring cost increases agency costs (incurred in the form of capital) and serves to reduce the steady state capital labor ratio. Now, a decline in k^* raises the marginal product of capital but reduces wages. *Ceteris paribus*, a lower level of efficiency wages can be sustained in equilibrium only if the unemployment rate is kept fairly high to 'discipline' workers.

6 The Underlying Nested Models

The model described thus far in fact nests three different models, one where only the labor market friction is active (as in, say, Jullien and Picard, 1998), one where only the credit market friction is active (as in, Boyd and Smith, 1998, for example), and of course, the full-information frictionless Diamond (1965) model. In this section we briefly sketch each of the nested models and analyze their stationary equilibria and stability properties. The purpose is to uncover the exact influence of each friction (in isolation) on the models' deeper features, and eventually compare them to the model with both frictions.

6.1 Model with Only Labor Friction

In most respects this is the classic Diamond model except that workers are of heterogenous types and firms issue efficiency wage contracts that keep the shirkers away at the cost of some unemployment. With no credit market friction, and all employed agents saving their entire wage income, we have

$$K_{t+1} = L_t \omega_t$$

and

$$R_{t+1} = f'(k_{t+1}).$$

We already know from (6) that $L_t = \digamma\left(\beta(1-\theta)\omega_t R^s_{t+1}\right)$. Here $R^s_{t+1} = R_{t+1} = f'(k_{t+1})$. Then,

$$k_{t+1} \equiv \frac{K_{t+1}}{L_{t+1}} = \frac{L_t \omega_t}{L_{t+1}} = \omega\left(k_t\right) \frac{\digamma\left(\hat{a}_t\right)}{\digamma\left(\hat{a}_{t+1}\right)}$$

Note that the supply of effective labor evolves according to

$$\frac{L_t}{L_{t+1}} = \frac{\digamma\left(\hat{a}_t\right)}{\digamma\left(\hat{a}_{t+1}\right)}$$

unlike in the classic Diamond model, where $L_t/L_{t+1} = 1$ for zero population growth. For future reference, we collect these results:

Lemma 2 *The equilibrium law of motion for the capital-labor ratio in the model with solely labor market friction is given by*

$$k_{t+1} = \omega\left(k_t\right) \frac{\digamma\left(\hat{a}_t\right)}{\digamma\left(\hat{a}_{t+1}\right)}, \tag{34}$$

$$\hat{a}_t = \beta(1-\theta)\omega(k_t) f'(k_{t+1}), \tag{35}$$

and the stationary equilibrium is a solution to

$$k = \omega\left(k\right). \tag{36}$$

To keep the comparisons fair and straightforward, we continue to assume a Cobb-Douglas technology so that

$$\begin{aligned} y_t &= A k_t^{\alpha}, \\ \omega_t &= (1-\alpha) A k_t^{\alpha}, \\ \rho_t &= \alpha k_t^{\alpha-1}. \end{aligned}$$

Thus, equation (34) becomes

$$k_{t+1} = (1-\alpha) A k_t^{\alpha} \frac{\digamma(\hat{a}_t)}{\digamma(\hat{a}_{t+1})} \tag{37}$$

Similarly, from (35) we obtain

$$\begin{aligned}\hat{a}_t &= \beta(1-\theta)(1-\alpha)Ak_t^{\alpha}\alpha Ak_{t+1}^{\alpha-1} \\ &\Rightarrow k_{t+1}^{1-\alpha} = \frac{\alpha\beta(1-\theta)(1-\alpha)A^2k_t^{\alpha}}{\hat{a}_t} \qquad (38)\end{aligned}$$

Rearranging (38) yields

$$\begin{aligned}k_{t+1} &= \left[\alpha\beta(1-\theta)(1-\alpha)A^2\right]^{1/(1-\alpha)} k_t^{\alpha/(1-\alpha)}\hat{a}_t^{-1/(1-\alpha)} \\ &\equiv \kappa k_t^{\alpha/(1-\alpha)}\hat{a}_t^{-1/(1-\alpha)}. \qquad (39)\end{aligned}$$

Substituting for k_{t+1} from (37) into (39), we obtain

$$\begin{aligned}F(\hat{a}_{t+1}) &= \left[\frac{(1-\alpha)A}{\kappa}\right]\frac{k_t^{\alpha}F(\hat{a}_t)}{k_t^{\alpha/(1-\alpha)}\hat{a}_t^{-1/(1-\alpha)}} \\ &\equiv \zeta k_t^{-\alpha^2/(1-\alpha)}\hat{a}_t^{1/(1-\alpha)}F(\hat{a}_t). \qquad (40)\end{aligned}$$

Equations (39) and (40) define a non-linear dynamic system in $(k_t, \hat{a}_t)$ whose steady-states $(k^*, \hat{a}^*)$ solve the equations

$$\begin{aligned}k^* &= \kappa(k^*)^{\alpha/(1-\alpha)}(\hat{a}^*)^{-1/(1-\alpha)} \\ F(\hat{a}^*) &= \zeta\,(k^*)^{-\alpha^2/(1-\alpha)}\,(\hat{a}^*)^{1/(1-\alpha)}\,F(\hat{a}^*)\end{aligned}$$

Proposition 5 *The steady-state $(k^*, \hat{a}^*)$ is a saddle.*

Proof. See Appendix C. ■

6.2 Model with Only Credit Friction

We shall next shut down the labor market friction and examine effects of credit market distortions. As in the standard Diamond model, we will now have full employment, $L_t = 1$ for all t. The active CSV friction influences the return on loans and deposits as defined in Lemma 1: $R_{t+1} = \psi f'(k_{t+1})/\{q - \omega(k_t)\}$. Under our assumption of zero first period consumption, using (22), we can rewrite (21) as

$$K_{t+1} = (\varphi\mu_t)\,\phi q = \phi\omega(k_t)$$

implying that

$$k_{t+1} \equiv \frac{K_{t+1}}{L_{t+1}} = \phi\omega(k_t)$$

Lemma 3 *The equilibrium law of motion for the capital-labor ratio in the model with solely a credit market friction is given by*

$$k_{t+1} = \phi\omega(k_t) \tag{41}$$

and the steady state by

$$k = \phi\omega(k).$$

Lemma 4 *Suppose $\phi\omega'(0) > 1$. Then, (41) has a unique asymptotically stable steady state.*

6.3 Full-information Diamond model

Straightforward arguments, as spelt out in Azariadis (1993) or von Thadden (1999) reveal that the law of motion for the capital-labor ratio in the Diamond model is given by

$$k_{t+1} = \omega(k_t) \tag{42}$$

while the steady state solves

$$k = \omega(k).$$

Lemma 5 *Suppose $\omega'(0) > 1$ and $\omega''(k) < 0$. Then, (42) has a unique asymptotically stable steady state.*

It is useful to contrast the stability properties of the non-trivial stationary solution in the benchmark Diamond model with that in Proposition 3. The model with both frictions produces a unique equilibrium path of $\{k_t, a_t\}$ that asymptotically converges to the stationary equilibrium $(k^*, \hat{a}^*)$. In contrast, the full-information Diamond model (under the assumption of Cobb-Douglas technology and so first-period consumption) produces a unique globally asymptotically stable steady state. Adding the two frictions does not fundamentally alter the stability properties of the steady-states, nor does it contribute to multiple equilibria of the kind that Betts and Bhattacharya (1998) and Acemoglu (2001) note.

6.4 Model Comparisons

To analyze how each type of friction impacts the long-run and short-run economic behavior, let us first collect information about the stationary equilibria in the four models discussed above. Define k_D^* to be the steady state capital-labor ratio in the full-information Diamond model, k_L^* to be the same in the model with the labor market friction, k_C^* for the model with just the credit market friction, and k_{LC}^*, the stationary capital-labor ratio for the model with both frictions.

Lemma 6 *Under the assumption of Cobb-Douglas technology,*

$$k_D^* = [A(1-\alpha)]^{\frac{1}{1-\alpha}}, \quad k_L^* = [A(1-\alpha)]^{\frac{1}{1-\alpha}},$$
$$k_C^* = [\phi A(1-\alpha)]^{\frac{1}{1-\alpha}}, \quad k_{LC}^* = [\phi A(1-\alpha)]^{\frac{1}{1-\alpha}},$$

where, as defined in Lemma 1,

$$\phi \equiv \hat{z} - \left(\frac{\gamma}{q}\right) G(\delta),$$

$\delta > 0$ *is a constant satisfying*

$$1 - \left(\frac{\gamma}{q}\right) g(\delta) - G(\delta) = 0,$$

and $\hat{z}$ *denotes the mean of* z*.*

To facilitate comparisons, we set $\hat{z} = 1$ and restrict ourselves to $\phi \in [0, 1]$. Moreover, note that when $\gamma = 0$, we have $\phi = 1$. In this case, all information is effectively public and the model behaves exactly as the full-information Diamond model. Now compare the steady-state capital-labor ratios across these four nested economies.

Proposition 6 *When* $\hat{z} = 1$*, the following relationship holds:* $k_{LC}^* = k_C^* < k_L^* = k_D^*$*. That is, the long-run capital-labor ratio is lowest for economies with credit market frictions and additionally, the labor market friction does not affect the long-run capital-labor ratio on its own.*

From Proposition 6, it follows that:

Corollary 1

$$\frac{\omega(k_L^*)}{\omega(k_{LC}^*)} = \left[\frac{k_L^*}{k_{LC}^*}\right]^{\alpha} = \frac{1}{\phi^{\frac{\alpha}{1-\alpha}}}, \quad \frac{f'(k_L^*)}{f'(k_{LC}^*)} = \left[\frac{k_L^*}{k_{LC}^*}\right]^{\alpha-1} = \phi.$$

We next compare the extent of credit rationing across two economies, one with just the credit market friction, and the other with both frictions. Using (20), the fraction of borrowers who obtain external financing, μ, in the two economies is given by

$$\mu_C^* = \frac{\omega(k_C^*)}{\varphi q}, \quad \mu_{LC}^* = \frac{\omega(k_{LC}^*)F(a_{LC}^*)}{\varphi q}$$

Recall that $F(a_{LC}^*) \leq 1$. Since $\omega(k_C^*) = \omega(k_{LC}^*)$, we then have

$$\frac{\mu_C^*}{\mu_{LC}^*} = \frac{\omega(k_C^*)}{\omega(k_{LC}^*)F(a_{LC}^*)} = \frac{1}{F(a_{LC}^*)} \geq 1.$$

Corollary 2 *The extent of credit rationing (fraction of borrowers who do not get funding) is higher in the economy with both frictions than in the economy with only the credit market friction.*

Finally, we turn to a comparison of the steady state unemployment rate defined by $u^* \equiv 1 - F(\hat{a}^*)$. Comparing unemployment rates is simply a matter of comparing employment $F(\hat{a}^*)$ in the two economies:

$$\begin{aligned} F(\hat{a}_L^*) &= F\left[\beta(1-\theta)\omega(k_L^*)f'(k_L^*)\right], \\ F(\hat{a}_{LC}^*) &= F\left[\beta(1-\theta)\omega(k_{LC}^*)\frac{\psi f'(k_{LC}^*)}{q-\omega(k_{LC}^*)}\right] \end{aligned}$$

Using results from Proposition 4, we note that:

Proposition 7 *Long-run unemployment is higher in the economy with both frictions than in the economy with only the labor market friction.*

7 Discussion and Concluding Remarks

Our results have a number of interesting implications for the short-run and long-run behavior of economies. The first key prediction follows from Proposition 6. Since the long-run capital-labor ratio in an economy with labor market friction is identical to that in a frictionless economy, labor market imperfections do not affect factor intensities across nations. In other words, if we are to explain persistent differences in output *per worker* across nations using our corresponding steady state variable y^*, differences in credit market efficiency would matter more compared to labor market frictions. In fact, level differences in y^* across nations are explained only upto the parameter composition ϕ.

It is well-known that, on their own, credit frictions are not substantive enough to explain the large income dispersions observed across the world (see Azariadis and Chakraborty, 1999, for instance). We can see this in our model by considering the ratio of y^* between two nations i and j which differ only in the parameters governing the distortions, and in particular, share identical preferences and technology. Then,

$$\frac{y_i^*}{y_j^*} = \left[\frac{\phi_i}{\phi_j}\right]^{\frac{1}{1-\alpha}}.$$

For concreteness, let i denote India and j denote the US; PPP-adjusted relative income per worker in these countries is about 0.10.[12] One measure of credit distortions in our model comes from observing the gap between lending and deposit rates, since verification costs drive a wedge between these two returns. Indeed, we find that the average lending rate for India between

[12] Output per worker (RGDPQW) for India and the US was respectively 6,216 and 64,537 for 2000 (Penn World Table, version 6.1).

1974-95 is around 17% and the real interest rate for 1970-95 around 1%, while for the US, the average lending rate for 1974-95 has been lower at 10% compared to a 1.6% real interest rate for 1970-95. In principle, we could use such data on loan and real interest rate spreads to calibrate the underlying cost parameter γ, and hence, ϕ. But the problem with such an approach is that lending rates are heavily managed in poorer countries and estimated returns at the aggregate level do not truly capture the degree of distortions. Additionally, these estimates are computed *ex post*, and include losses on non-performing loans.

In fact, more carefully collected evidence (from both formal and informal credit markets) in the micro-development literature suggests much greater costs of intermediation than the macro-evidence indicates. For instance, Banerjee (2001, p. 9) notes that, "intermediation costs seem to eat up at least a third, and often half (and sometimes much more than half) of the income that would go to depositors". A quick way to see what such costs might do is to assume that $\phi_i = 1/2$ while $\phi_j = 1$ (that is, US credit markets are frictionless). With $\alpha = 1/3$, this difference in returns implies an income gap of about 0.35, which widens to 0.25 if we allow α to be 1/2.

An alternative way to gauge the impact of credit distortions would be to directly consider the extent of credit rationing. Using (20) and the expression for k^*, it is easy to show that

$$\frac{y_i^*}{y_j^*} = \frac{\mu_i^*}{\mu_j^*}.$$

Countries with less widespread access to external finance are expected to have lower output per worker. Objective measures of credit rationing are hard to come by, although firms in transition and developing countries do identify availability of external finance as a serious constraint (World Bank, 2000). But note that even if we were to assume universal access to external finance in the US, that is, $\mu_j^* = 1$, we would need μ_i^* for India to be implausibly low at 10% to match an income gap of 0.10.

While these predicted gaps for y^* do not come close to observed magnitudes, this is not to suggest that the welfare effects of better credit markets are insignificant. Indeed, reducing credit distortions in a poor country like India to levels similar to that in the U.S. (doubling ϕ_i to 1 for instance) could result in a quadrupling of output per worker! At the same time, in one particular respect, our computations above underestimate the true impact of distortions: welfare is more accurately measured by output per capita, $\widetilde{y}$, instead of the output per worker we have been using.[13]

[13] Data on output per worker and output per capita, for example in the Penn World Table 6.1, are highly correlated. However, empirical estimates of GDP per worker use the total "economically active population" as a measure of the workforce, and therefore corresponds more closely to $\tilde{y}$ than y in our model.

Our model assumes that unemployed workers produce (and consume) nothing and therefore, do not contribute to aggregate output. This is a simplifying assumption. More plausibly, consider a modified environment where the labor frictions are more relevant for formal (manufacturing) sector employment, while individuals unable to find jobs in that sector work in a low productive informal sector.[14] Labor frictions, in this case, result in segmented labor markets which are at the center of a large body of development literature (see Loayza, 1996 and Maloney, 1997). Suppose that informal sector output per worker is $\varpi < \omega(k_0)$, produced at a zero disutility cost of labor. The steady-state income per capita is given by the weighted average of formal and informal sector output:[15]

$$\tilde{y}^* = [1 - u^*]y^* + u^*\varpi. \tag{43}$$

If the rich country j were to have no credit market distortions (hence, no informal sector), the ratio of per capita incomes in the two countries would be given by

$$\frac{\tilde{y}_i^*}{\tilde{y}_j^*} = [1 - u_i^*]\frac{y_i^*}{y_j^*} + u_i^*(\varpi_i/y_i^*).\frac{y_i^*}{y_j^*}$$

Income levels are now affected by both frictions. Labor frictions, in particular, alter the composition of aggregate economic activity through u^*, shifting it in favor of the low-productivity informal sector. At the same time credit frictions have a *multiplier effect* on the economy: not only do they directly lower steady-state output in the modern sector (y^*) through lower capital accumulation, they also result in less formal sector employment ($1 - u^*$), pushing the economy into relatively low-return economic activities. To gauge what the two frictions together do, suppose that the informal sector accounts for as much as 50% of employment in country i, that is, $u_i^* = 1/2$ ($u_j^* = 0$).[16] Moreover suppose that it is only half as productive as the formal sector, $\varpi_i/y_i^* = 1/2$. The same output per worker ratio of 0.25 that we predicted above (for the formal sector under $\alpha = 1/2$, $\phi_i = 1/2$ and $\phi_j = 1$) now implies an even lower per capita income gap, about 0.19. Increasing the share of informal sector employment to 70%, widens this income disparity to 0.16.

[14] For instance, one could think of the disutilities of working in the manufacturing sector as arising from a regimented lifestyle, possible long commutes and extended work-hours.

[15] Loyaza (1996) reports that informal sector output relative to total GDP ($u^*\varpi/\tilde{y}^*$) for Latin American countries range from around 18% for Argentina to nearly 66% for Bolivia.

[16] The International Labor Organization (2001) reports: "In 17 out of 54 economies studied, employment in the informal, or related, sectors accounts for more than 50 per cent of total employment in the corresponding branches of economic activity. These economies include nine in Africa, seven in Latin America, and one in Asia (Pakistan). The highest shares (more than 70 per cent) were recorded in Gambia, Ghana, Mali and Uganda." See ILO (2001) "Key Indicators of the Labor Market".

These numbers still do not come close to the large disparities in income per capita we observe in the world. But credit and labor market frictions jointly seem to explain a significant fraction of these actual gaps, especially since we have not even allowed these frictions to affect technology. Moreover, our computations suggest that when relative income gaps are modest, credit and labor market frictions are likely to be more important. The presence of greater credit and labor market frictions in Europe relative to the US, for example, is well-documented. Our model indicates that institutional imperfections in these two markets could well account for bulk of the difference in living standards in these two regions.

A second key prediction of our model pertains to the short-run effects of labor market frictions. An exogenous increase in labor market frictions, occurring through θ for instance, increases long-run unemployment but not the steady-state capital-labor ratio. In the short-run, the higher unemployment has two effects: it reduces the flow of loanable funds into the financial sector, and lowers returns to capital so that capital accumulation is lower. In the long-run, the aggregate capital stock adjusts downward to bring back the capital-labor ratio to its previous level.

This also suggests that, for business cycle movements, labor market frictions in conjunction with credit frictions have the ability to amplify temporary shocks and exacerbate recessions. For example, consider a one-time (exogenous) adverse shock to the Solow-residual A at time t. This immediately lowers the wage ω_t, and reduces the flow of loanable funds. At the same time, it lowers borrower net worth, leading to a greater fraction of capitalists being credit-constrained. The credit friction margin, working through borrowing constraints, amplifies the temporary shock on its own. But the presence of labor frictions worsens the impact: a lower wage rate leads to greater unemployment, and thereby elicits an even steeper decline in investment.

The importance of information frictions in explaining business cycle movements has been discussed by a number of authors in recent years, Greenwald and Stiglitz (1994) and Arnold (2002) being two examples. Our model provides a tractable framework to quantitatively assess how well these frictions explain observed business cycle movements in investment, employment and output. It is apparent that the overlapping generations framework adopted here would have to be abandoned in favor of the infinite-horizon model. As Carlstrom and Fuerst (1997) have demonstrated, the credit friction margin is easily extended to such an environment. Similarly, Gomme (1999) offers a way to incorporate the shirking and efficiency wage model into the infinite-horizon model. It is conceivable that these settings can be profitably married to study the joint influence of the two frictions on variables at the business cycle frequency. This would be an interesting issue for future research.

Appendix

A Proof of Proposition 3

As described earlier in the text, the steady-states $(k^*, \hat{a}^*)$ solve the two equations:

$$\begin{aligned} k^* &= \eta G(k^*)(\hat{a}^*)^{-1/(1-\alpha)}, \\ F(\hat{a}^*) &= \sigma H(k^*) F(\hat{a}^*)(\hat{a}^*)^{1/(1-\alpha)}. \end{aligned}$$

These can be solved to obtain

$$k^* = [\eta\sigma(1-\alpha)A]^{1/(1-\alpha)}, \ \hat{a}^* = \left[\frac{\eta G(k^*)}{k^*}\right]^{1-\alpha}.$$

Note here that

$$G'(k) = G(k)\frac{\alpha}{k}\frac{q}{q-\omega(k)} > 0$$

and

$$H'(k) = -H(k)\frac{\alpha}{k}\frac{\omega(k)}{q-\omega(k)} < 0.$$

Let us log-linearize equation (30) around the steady-states $(k^*, \hat{a}^*)$:

$$k_{t+1} - k^* = \eta G'(\hat{a}^*)^{-1/(1-\alpha)}(k_t - k^*) - \eta\frac{1}{1-\alpha}G(\hat{a}^*)^{-1/(1-\alpha)}\frac{1}{\hat{a}^*}(\hat{a}_t - \hat{a}^*)$$

which combined with the steady-state equation gives

$$\breve{k}_{t+1} = \alpha\left[\frac{q}{q-\omega(k^*)}\right]\breve{k}_t - \frac{1}{1-\alpha}\breve{a}_t, \qquad (44)$$

where we have defined the variable $\breve{x}_t \equiv (x_t - x^*)/x^* \equiv \ln(x_t/x^*)$.

Linearizing (31) in a similar manner and using, we obtain

$$\begin{aligned} f(\hat{a}^*)(\hat{a}_{t+1} - \hat{a}^*) \quad &= \quad -\alpha\sigma H(k^*)F(\hat{a}^*)(\hat{a}^*)^{1/(1-\alpha)}\left[\frac{\omega(k^*)}{q-\omega(k^*)}\right]\frac{k_t - k^*}{k^*} + \\ & \quad\ \sigma H(k^*)F(\hat{a}^*)(\hat{a}^*)^{1/(1-\alpha)}\left[\frac{\hat{a}^* f(\hat{a}^*)}{F(\hat{a}^*)} + \frac{1}{1-\alpha}\right]\frac{\hat{a}_t - \hat{a}^*}{\hat{a}^*}. \end{aligned}$$

Using the definition of $\hat{a}^*$, this simplifies to

$$f(\hat{a}^*)(\hat{a}_{t+1} - \hat{a}^*) = -\alpha F(\hat{a}^*)\left[\frac{\omega(k^*)}{q-\omega(k^*)}\right]\hat{k}_t + F(\hat{a}^*)\left[\frac{\hat{a}^* f(\hat{a}^*)}{F(\hat{a}^*)} + \frac{1}{1-\alpha}\right]\hat{a}_t$$

or,

$$\breve{a}_{t+1} = \frac{F(\hat{a}^*)}{\hat{a}^* f(\hat{a}^*)}\left[-\alpha\left\{\frac{\omega(k^*)}{q-\omega(k^*)}\right\}\hat{k}_t + \left\{\frac{\hat{a}^* f(\hat{a}^*)}{F(\hat{a}^*)} + \frac{1}{1-\alpha}\right\}\breve{a}_t\right]. \qquad (45)$$

Equations (44) and (45) define a two-dimensional linear dynamic system

$$\mathbf{x}_{t+1} = \mathbf{Q}\mathbf{x}_t$$

where $\mathbf{x}_t \equiv [\breve{k}_t \quad \breve{a}_t]'$ and the Jacobian matrix $\mathbf{Q}$ is defined by its elements

$$\begin{array}{ll} q_{11} = \frac{\alpha q}{q-\omega(k^*)}, & q_{12} = -\frac{1}{1-\alpha} \\ q_{21} = -\left(\frac{\alpha w(k^*)}{q-\omega(k^*)}\right)\left(\frac{F}{\hat{a}^* f}\right), & q_{22} = 1 + \frac{1}{1-\alpha}\left(\frac{F}{\hat{a}^* f}\right) \end{array}$$

Clearly, the trace and determinants of $\mathbf{Q}$ are

$$\begin{aligned} T &= q_{11} + q_{22} = 1 + \frac{\alpha q}{q - \omega(k^*)} + \frac{1}{1-\alpha}\left(\frac{F}{\hat{a}^* f}\right) > 0, \\ D &= q_{11}q_{22} + q_{21}q_{12} = \frac{\alpha q}{q - \omega(k^*)}\left[1 + \frac{1}{1-\alpha}\left(\frac{F}{\hat{a}^* f}\right)\right] - \frac{1}{1-\alpha}\left(\frac{\alpha w(k^*)}{q-\omega(k^*)}\right)\left(\frac{F}{\hat{a}^* f}\right) \\ &= \frac{\alpha q}{q - \omega(k^*)} + \frac{\alpha}{1-\alpha}\frac{F}{\hat{a}^* f} > 0. \end{aligned}$$

Consider now the characteristic equation whose two roots (λ_1, λ_2) satisfy

$$p(\lambda) = \lambda^2 - T\lambda + D = (\lambda - \lambda_1)(\lambda - \lambda_2) = 0.$$

Since

$$p(0) = D > 0,$$

evidently the eigenvalues fall on the same side of 0.

Again, since

$$\begin{aligned} p(1) &= 1 - T + D \\ &= 1 - 1 - \frac{\alpha q}{q - \omega(k^*)} - \frac{1}{1-\alpha}\left(\frac{F}{\hat{a}^* f}\right) + \frac{\alpha q}{q - \omega(k^*)} + \frac{\alpha}{1-\alpha}\frac{F}{\hat{a}^* f} = -\frac{F}{\hat{a}^* f} < 0, \end{aligned}$$

the eigenvalues must fall on opposite sides of 1. Thus, the steady-state $(k^*, \hat{a}^*)$ is a saddle-point with eigenvalues $\lambda_1 > 1$ and $0 < \lambda_2 < 1$.■

B Proof of Proposition 4

Define $\chi \equiv \alpha(1-\alpha)\beta q(1-\theta)A^2$. From (33) it follows that

$$\hat{a}^* = \chi\psi\left[\frac{(k^*)^{2\alpha-1}}{q - (1-\alpha)A\,(k^*)^{\alpha}}\right]$$

and $k^* = [(1-\alpha)\phi A]^{1/(1-\alpha)}$, where ϕ and ψ, defined in Lemma 1 above, are reproduced below for convenience:

$$\psi \equiv q\left[\delta - \left(\frac{\gamma}{q}\right)G(\delta) - \int_0^{\delta} G(z)dz\right],$$

$$\phi \equiv \hat{z} - \left(\frac{\gamma}{q}\right) G(\delta).$$

For future reference,

$$\frac{\partial \phi}{\partial \gamma} = -\left(\frac{1}{q}\right) G(\delta)$$
$$\frac{\partial \psi}{\partial \gamma} = -G(\delta)$$
$$\frac{\partial k^*}{\partial \gamma} = -\frac{k^*}{(1-\alpha)\phi q} G(\delta)$$

so that $\partial\psi/\partial\gamma$ may be rewritten as $\partial\psi/\partial\gamma = [\{(1-\alpha)\phi q\}/(k^*)](\partial k^*/\partial\gamma)$. Now differentiating $\hat{a}^*$gives us

$$\begin{aligned}\frac{1}{\chi}\frac{\partial \hat{a}^*}{\partial \gamma} &= \left[\frac{(k^*)^{2\alpha-1}}{q-(1-\alpha)A(k^*)^{\alpha}}\right]\frac{\partial \psi}{\partial \gamma} + \\ & \psi\left[\frac{(2\alpha-1)(k^*)^{2\alpha-2}}{q-(1-\alpha)A(k^*)^{\alpha}} + \frac{\alpha(1-\alpha)A(k^*)^{3\alpha-2}}{[q-(1-\alpha)A(k^*)^{\alpha}]^2}\right]\frac{\partial k^*}{\partial \gamma}\end{aligned}$$

which simplifies to

$$\left[\frac{(1-\alpha)\phi q}{q-(1-\alpha)A(k^*)^{\alpha}} + \frac{(2\alpha-1)\psi}{q-(1-\alpha)A(k^*)^{\alpha}} + \frac{\alpha(1-\alpha)\psi A(k^*)^{\alpha}}{[q-(1-\alpha)A(k^*)^{\alpha}]^2}\right](k^*)^{2\alpha-2}\frac{\partial k^*}{\partial \gamma}$$

Recall $\partial k^*/\partial\gamma < 0$. Therefore, in order that, $\partial\hat{a}^*/\partial\gamma < 0$ we require the term inside the brackets to be positive. That is, we require

$$\frac{(1-\alpha)\phi q}{q-(1-\alpha)A(k^*)^{\alpha}} + \frac{(2\alpha-1)\psi}{q-(1-\alpha)A(k^*)^{\alpha}} + \frac{\alpha\psi(1-\alpha)A(k^*)^{\alpha}}{[q-(1-\alpha)A(k^*)^{\alpha}]^2} > 0$$

Recall that $\omega(k^*) = (1-\alpha)A(k^*)^{\alpha}$. Then, this last condition simplifies to

$$(1-\alpha)\frac{\phi q}{\psi} + (2\alpha-1) + \frac{\alpha\omega(k^*)}{q-\omega(k^*)} > 0$$

and further to

$$(1-\alpha)\frac{\phi q}{\psi} + \frac{\alpha\omega(k^*)}{q-\omega(k^*)} + 2\alpha > 1.$$

Recall from Assumption 2 that $(1-\alpha)\phi q/\psi \geq 1$. Since $q > \omega(k^*)$, the inequality above is always satisfied.■

C Proof of Proposition 5

To investigate stability of the steady-states, we shall log-linearize the system described by equations (37) and (38). Equations (39) and (40) define a non-linear dynamic system in $(k_t, \hat{a}_t)$. The steady-states of this system $(k^*, \hat{a}^*)$ solve the pair of equations

$$\begin{aligned} k^* &= \kappa (k^*)^{\alpha/(1-\alpha)} (\hat{a}^*)^{-1/(1-\alpha)} \\ F(\hat{a}^*) &= \zeta\, (k^*)^{-\alpha^2/(1-\alpha)}\, (\hat{a}^*)^{1/(1-\alpha)}\, F(\hat{a}^*) \end{aligned}$$

To linearize the system, we shall use the approximation that $\ln(1+x) \simeq x$ so that $\ln(z) \simeq z-1$. Using this we can write $(z_t - z^*)/z^* = (z_t/z^*) - 1 \simeq \ln(z_t/z^*) \equiv \breve{z}_t$.

Begin by linearizing equation (39):

$$\begin{aligned} k_{t+1} - k^* &= \frac{\alpha}{1-\alpha} \kappa (k^*)^{\alpha/(1-\alpha)} (\hat{a}^*)^{-1/(1-\alpha)} \left[\frac{k_t - k^*}{k^*} \right] \\ &\quad - \frac{1}{1-\alpha} \kappa (k^*)^{\alpha/(1-\alpha)} (\hat{a}^*)^{-1/(1-\alpha)} \left[\frac{\hat{a}_t - \hat{a}^*}{\hat{a}^*} \right] \end{aligned}$$

which, using the expression for k^*, becomes

$$\begin{aligned} \frac{k_{t+1} - k^*}{k^*} &= \frac{\alpha}{1-\alpha} \left[\frac{k_t - k^*}{k^*} \right] - \frac{1}{1-\alpha} \left[\frac{\hat{a}_t - \hat{a}^*}{\hat{a}^*} \right] \\ &\Rightarrow \breve{k}_{t+1} = \frac{\alpha}{1-\alpha} \breve{k}_t - \frac{1}{1-\alpha} \breve{a}_t \end{aligned} \tag{46}$$

Similarly, linearizing (40) we get

$$\begin{aligned} f(\hat{a}^*)(\hat{a}_{t+1} - \hat{a}^*) &= -\frac{\alpha^2}{1-\alpha} [\zeta\, (k^*)^{-\alpha^2/(1-\alpha)}\, (\hat{a}^*)^{1/(1-\alpha)}\, F(\hat{a}^*)] \left[\frac{k_t - k^*}{k^*} \right] \\ &\quad + \frac{1}{1-\alpha} [\zeta\, (k^*)^{-\alpha^2/(1-\alpha)}\, (\hat{a}^*)^{1/(1-\alpha)}\, F(\hat{a}^*)] \left[\frac{\hat{a}_t - \hat{a}^*}{\hat{a}^*} \right] \\ &\quad + [\zeta\, (k^*)^{-\alpha^2/(1-\alpha)}\, (\hat{a}^*)^{1/(1-\alpha)}\, F(\hat{a}^*)] \frac{\hat{a}^* f(\hat{a}^*)}{F(\hat{a}^*)} \left[\frac{\hat{a}_t - \hat{a}^*}{\hat{a}^*} \right], \end{aligned}$$

or, using (**??**),

$$f(\hat{a}^*)(\hat{a}_{t+1} - \hat{a}^*) = -\frac{\alpha^2}{1-\alpha} F(\hat{a}^*) \breve{k}_t + \frac{1}{1-\alpha} F(\hat{a}^*) \breve{a}_t + F(\hat{a}^*) \frac{\hat{a}^* f(\hat{a}^*)}{F(\hat{a}^*)} \breve{a}_t$$

or,

$$\breve{a}_{t+1} = \frac{F}{f} \left[-\frac{\alpha^2}{1-\alpha} \frac{1}{a^*} \breve{k}_t + \left\{ \frac{1}{1-\alpha} \frac{1}{a^*} + \frac{f}{F} \right\} \breve{a}_t \right] \tag{47}$$

Equations (46) and (47) can be written in matrix notation as

$$\mathbf{x}_{t+1} = \mathbf{Q} \mathbf{x}_t.$$

The elements of the Jacobian $\mathbf{Q}$ are

$$\begin{aligned} q_{11} &= \tfrac{\alpha}{1-\alpha}, & q_{12} &= -\tfrac{1}{1-\alpha} \\ q_{21} &= -\left(\tfrac{\alpha^2}{1-\alpha} \right) \left(\tfrac{F}{a^* f} \right), & q_{22} &= 1 + \tfrac{1}{1-\alpha} \left(\tfrac{F}{a^* f} \right) \end{aligned}$$

The eigenvalues of $\mathbf{Q}$ satisfy the characteristic equation

$$p(\lambda) \equiv \lambda^2 - T\lambda + D = 0,$$

where

$$\begin{aligned} T &= q_{11} + q_{22} = 1 + \frac{\alpha}{1-\alpha} + \frac{1}{1-\alpha}\left(\frac{F}{\hat{a}^* f}\right) > 0, \\ D &= q_{11}q_{22} - q_{12}q_{21} = \frac{\alpha}{1-\alpha}\left[1 + \left(\frac{F}{\hat{a}^* f}\right)\right] > 0. \end{aligned}$$

Therefore,

$$p(0) = D > 0$$

suggesting that the two roots (λ_1, λ_2) fall on the same side of 0.

Moreover,

$$p(1) = 1 - T + D = -\left(\frac{F}{\hat{a}^* f}\right)\left[\frac{1}{1-\alpha} - \frac{\alpha}{1-\alpha}\right] = -\left(\frac{F}{\hat{a}^* f}\right) < 0$$

which implies that (λ_1, λ_2) fall on either sides of 1. Hence, we have $\lambda_1 > 1$ and $0 < \lambda_2 < 1$ so that the steady-state $(k^*, \hat{a}^*)$ is a saddle-point.■

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