THY NEIGHBOR'S KEEPER: THE DESIGN OF A CREDIT COOPERATIVE WITH THEORY AND A TEST*

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Economists now appreciate that resource allocation in less economically developed economies is profoundly influenced by nonfirm economic institutions. However, our theories of nonfirm institutions often suggest different answers to many questions including those of policy. This paper illustrates a method for discriminating between alternative theories using data from German credit cooperatives from nineteenth and early twentieth century Germany. We build a model of credit cooperatives designed to provide monitoring incentives and test this using nineteenth century data.

I. INTRODUCTION

Economists now appreciate that resource allocation in less developed economies is influenced by nonfirm economic institutions such as credit cooperatives, sharecropping [Stiglitz 1974], market interlinkages [Braverman and Stiglitz 1982], rotating savings and credit associations [Besley, Coate, and Loury 1993], gift exchange arrangements, and the extended family. However, while an extensive body of literature has gone into understanding the way in which firms are organized (see, for example, Williamson [1975]), our understanding of nonfirm institutions is limited to a number of alternative theories about the possible function served by a particular institution. (An exception is Eswaran and Kotwal [1985].) These theories are all plausible but imply different answers to policy and other questions. In this paper we illustrate a method for discriminating between them, using the example of Germany's nineteenth century credit cooperatives.

There are three main reasons why cooperatives might function better than conventional banking arrangements in less developed economies. The first, essentially sociological, view stresses the role of the community in sustaining nonopportunistic behavior among participants. Social sanctions are typically not available to a

conventional bank, but are available in a co-op [Besley and Coate 1992]. The second view sees the cooperative as sustained by repeated interactions among the participants. Both of these views are similar in giving reasons why privately optimal, shortsighted behavior may be curtailed in a credit cooperative. The policy implications of these two views are also similar: cooperatives should be designed to ensure that members have durable long-term relations among themselves or else identify sufficiently with the collective. Thus, we treat these two as a single hypothesis, which we call the *long-term interaction* view of credit cooperatives.

We compare this with the hypothesis that a cooperative provides an efficient way to induce monitoring of borrowers which, following Stiglitz [1990], we call the *peer monitoring* view.[1] Although the community lacks capital, necessitating outside funding from a bank, neighbors are assumed to have better information about borrowers than banks. The efficient outcome is then to have community-based monitoring, an idea first analyzed in Varian [1989] and Stiglitz [1990]. For such monitoring to be effective, the cooperative's structure must create incentives for its members to monitor one another.

This view thus predicts that a cooperative will adopt a constitution that provides monitoring incentives. Here, we suggest three ways in which this can be done.

1. The other members of the cooperative may be made liable, in whole or in part, for any loan on which the cooperative defaults.

2. Part of each loan may be financed by another cooperative member, so that if the borrower defaults, then the other co-op members also lose something.

3. The interest on the part of the loan financed by other members may be increased, enhancing the members' stake in ensuring that the loan is repaid.

Our model is of a Principal (the bank), Supervisor (the nonborrowing co-op member), and an Agent (the borrower). While such models have been studied in general (see Tirole [1988]), we use the German cooperatives as a template for restricting the model, giving us a basis for characterizing the optimal organizational form. The model is also of interest in the context of the burgeoning literature on nonmarket credit institutions reviewed in

1. That monitoring is an important aspect of cooperatives is succinctly captured in Fagneux [1908]. He refers to the small villages as places "where one's eyes are so attentive to what occurs among the neighbors" [p. 39] (authors' translation).

Besley [1993]. Liability, borrowing from inside, and the interest paid to members are the three instruments that are optimally chosen by each cooperative.

Although the data from nineteenth century Germany are not extensive enough to permit formal statistical testing of hypotheses, they are invaluable for the current exercise. The choice of instruments in Germany was made at the cooperative level, making it possible for the constitution to reflect optimally its idiosyncratic environment. The long time-horizon for the data also makes it likely that each cooperative adopted its best constitutional form. In Ireland the life of the cooperatives was short, reflecting poor institutional design (see Guinnane [1994]).

Our *test* of the peer monitoring view has two main limitations. First, we have no direct evidence on the optimality of the chosen instruments. Instead, we derive the comparative-static properties and compare these with cross-sectional data on cooperatives. Second, the long-term interaction and peer monitoring views are *not* inconsistent. Hence, finding that the predictions of the peer monitoring model agree with the data does not necessarily prove that this is the correct model. We can only find evidence *against* this view by finding that its comparative statics do not fit the data.

The remainder of the paper is organized as follows. In Sections II–IV we construct a model of the optimal credit cooperative and derive some predictions from it. Section V tests these predictions against the data on the nineteenth century cooperatives. Section VI contains concluding remarks.

II. THE MODEL

The model is based on the structure of the German cooperatives. Although our representation is inevitably stylized, the structure of the model captures the salient features of the institutions. We discuss the correspondence between the model and historical cooperatives briefly at the end of Section III and in detail in Section V.

The cooperative has two members each of whom owns two assets; a plot of land and monetary wealth of k. At the beginning of time, nature endows (only) one co-op member with an opportunity to make his land more productive. This requires an investment of $K + k$ units of capital, thus necessitating a loan if it is to be undertaken. The other member is assumed to have no opportunity to invest and receives a deterministic return of θ on his land. We

assume that $k < K$, implying that total monetary wealth within the co-op is insufficient to finance the investment. Thus, some part of the loan must be obtained from outside sources. The cooperative borrows b from outside, and the monitor lends $K - b$ to the borrower. We denote the interest rate to be paid on outside funds by R and on inside funds by r.[2]

The nonborrowing member serves three potential functions. First, he is a lender. Second, he is a guarantor and hence may stand liable if the borrower fails to repay some of what is owed to the outside borrower. We denote the amount of this liability by $l(\leq bR)$. Finally, he may monitor the borrower.

Once funds for the project are in place, the nonborrower chooses his monitoring level to affect the borrower's project choice. The borrower selects a project, whose return is subsequently realized. If he has sufficient funds, then the borrower repays the monitor and the outside lender. Otherwise, he defaults and the monitor has to pay out l.

The monitor can also earn a return on his monetary wealth outside the co-op. He has access to an outside opportunity on which he receives a gross return of ρ. However, the net return is $\rho - \delta$, where δ can be positive or negative in general. A positive δ might represent the fact that the cooperative is a more convenient repository for funds, while a negative value of δ represents a case in which the outside bank yields other services (e.g., advice) unavailable in the co-op. Since the borrower may default, the return to lending inside the co-op must compensate the nonborrowing member for the risk that he bears. Thus, r must be at least as high as the nonborrower's opportunity cost of funds allowing for the possibility of default. The cooperative's constitution is defined in terms of (b,l,r): the amount of internal borrowing, the liability of the nonborrowing member, and the interest rate paid on internal borrowing.

III. Project Selection

Projects are selected by the borrower but can be influenced by the nonborrowing member. This section characterizes this project choice as a function of (b,l,r). Projects are indexed by a success

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2. We assume that $\theta > R$ to ensure that the nonborrower's wealth is greater than the maximum amount that he could be required to pay to the outside lender.

probability: $\pi \in [\underline{\pi},1]$. A project yields some return with probability π and nothing otherwise. The expected return from a project is denoted by $E(\pi) \equiv \pi\phi(\pi)$. We assume that $E'(\pi) > 0$ and $\phi'(\pi) < 0$. The first of these says that *projects with higher expected returns are also safer.*

   Let ρ denote the lender's opportunity cost of funds. The interest rate paid on outside funds in a competitive credit market is found using the lender's zero profit condition:

$$(1) \qquad\qquad \pi R b + (1 - \pi)l = \rho b.$$

With probability π the loan is repaid, and with probability $(1 - \pi)$ the lender receives an amount l from the nonborrowing member. The cost of funds is ρb. Solving for R in (1), the total interest payment owed on any project is

$$(2) \quad \bar{r} \equiv bR + (K - b)r = (\rho b - (1 - \pi)l + (K - b)r\pi)/\pi,$$

which is just the sum of repayments on borrowing from outside and inside sources. To capture the idea that the borrower will choose projects that are too risky from a social point of view, we assume that

$$(3) \qquad\qquad \pi(\phi(\pi) - \rho K)$$

is *decreasing* in π. Thus, if he could borrow at the outside lender's opportunity cost of funds, ρ, the borrower would find it worthwhile to choose the riskiest project $\underline{\pi}$. This would be inconsistent with the lender breaking even, necessitating a higher interest rate. The lender prefers a high π while the borrower prefers a low one.

   The nonborrowing member can affect the project choice. We model this as a penalty imposed on the borrower if he chooses $\underline{\pi}$. Thus, for a project π to be selected, it must be preferred to choosing $\underline{\pi}$ and paying the penalty c. The borrower will select the project π, therefore, if it satisfies the following incentive compatibility constraint:

$$(4) \qquad\qquad \pi(\phi(\pi) - \bar{r}) \geq \underline{\pi}(\phi(\underline{\pi}) - \bar{r}) - c.$$

The monitor chooses c and, we assume, is committed to punishing the borrower if he deviates to $\underline{\pi}$. This abstracts from two problems. First, the borrower is not allowed to bribe the monitor to change his behavior. Second, we ignore the fact that the punishment may not be credible because it is costly for the monitor to inflict. The

cost of imposing a penalty c, is given by an increasing and convex function, $M(c)$.[3]

The monitor is assumed to set c before the borrower chooses π. The project chosen in equilibrium will be that for which (4) is an equality (assuming an interior solution). But since *in equilibrium* $\bar{r}$ depends upon π and the vector (b,l,r) via (2), the equilibrium project can be written as the fixed point relationship:

$$(5) \qquad \pi = h(\bar{r}(\underline{\pi},b,l,r),c),$$

derived from (4). The value of π that satisfies (4) is unique if $\partial h(\cdot)/\partial \bar{r} \cdot \partial \bar{r}/\partial \pi < |1|$ which holds if $\underline{\pi}$ is large enough,[4] so that we can write $\pi = g(b,l,r,c)$ to represent the project chosen as a function of the three parameters representing the co-op's design and the penalty level chosen by the monitor.

We now investigate how the choice of π depends upon the cooperative's design, holding c fixed (see Appendix A for details). Such effects are mediated through the interest payment $\bar{r}$. Since an increase in the liability on the nonborrower, l, reduces the interest rate required by the outside lender, it raises π. An increase in r has the opposite effect since it raises $\bar{r}$. The effect of changing b depends upon the sign of $(R - r)$; whether a change in the balance of financing between inside and outside sources raises or lowers the interest rate depends upon whether inside or outside capital is cheaper.

The monitor chooses c to maximize $\pi(K - b) - (1 - \pi)l - M(c)$, recognizing that π is determined by the function $h(\cdot)$. This yields the first-order condition:

$$(6) \qquad ((K - b)r + l)\,\frac{\partial h}{\partial c} = M'(c).$$

The term multiplying $\partial h/\partial c$ represents the gain to the nonborrower of the project being successful over its failure, and thus measures the incentive for the monitor to increase π. Solving (6)

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3. The penalty is never actually imposed in equilibrium. We assume, however, that it is costly for the nonborrowing member of the co-op to put himself in a position to penalize if necessary. Costs of imposing penalities may thus partly reflect information gathering, but also the fact that a monitor may have to rearrange his affairs to watch over the borrower at crucial stages of the project. Because there is only one monitor, there is no free-rider problem in monitoring here, which may arise for large co-ops.

4. *Proof.* Note that $\partial h/\partial \pi = \{(\pi - \underline{\pi})\partial \bar{r}/\partial \pi\}/(E'(\pi) - \bar{r}) = \{(\pi - \underline{\pi})/\underline{\pi}\}(Rb - l)/\pi(\bar{r} - R'(\pi))$. Since the first term in $\{\cdot\}$ goes to zero as $\underline{\pi} \to 1$ and the second term in $\{\cdot\}$ is bounded, the claim follows.

yields $c = f(b,l,r,\pi)$, i.e., the penalty choice as a function of the co-op's design and the project chosen.

To investigate the comparative static properties of (6), there are two effects to consider (see Appendix A). The first, or *direct* effect, operates via changes in $((K - b)r + l)$ and the second, or *indirect* effect, via the impact of (b,l,r) on $\partial h / \partial c$ operating through the interest payment $\bar{r}$. The latter represents how the co-op's design affects the *marginal* impact of c on project selection. An increase in l raises the incentive to monitor directly and also raises $\partial h / \partial c$ when it reduces $\bar{r}$. Thus, more liability increases c other things being equal. The effect of an increase in r is ambiguous. Its direct effect encourages monitoring, but it also raises $\bar{r}$ yielding an unfavorable indirect effect. Finally, an increase in b reduces incentives for the nonborrower to engage in costly monitoring if $R > r$. The direct effect always discourages monitoring and the indirect effect is also negative if $\bar{r}$ is increased, which it will be if $R > r$.

Equilibrium values of c and π are obtained as fixed points of the mappings $\pi = g(b,r,l,c)$ and $c = f(b,r,l,\pi)$ (see Appendix A for details). These are denoted by $c^*(b,r,l)$ and $\pi^*(b,l,r)$. Thus, project selection and the monitor's choice can be written as functions of the co-op's design. This will prove useful in the next section which investigates how these parameters should optimally be set within a cooperative.

The model makes several specific assumptions that are based on the nineteenth century German institutions. We discuss a defense of a number of these here. First, we have ruled out collateral. In doing so, we appeal to the fact that land collateralization worked imperfectly and that the cooperative's members were mainly those with few assets to pledge. In any case, introducing *partial* collateralization would not change anything of substance. Second, our assumption that the return on internal funds must exceed their opportunity cost reflects the reality that cooperative members could use other financial intermediaries as repositories for their savings if they wished. In reality, as we discuss further below, the interest rate in cooperatives was most often higher than that available outside. In any case, it would have been difficult to force individuals to deposit their savings in a cooperative. Third, we assumed away partial default. As far as we know, this was treated just the same as full default, leading to ejection from the cooperative. This is plausible given that there were probably natural indivisibilities in punishments such as social ostracism or being

ejected from the co-op, making the punishment for partial default much the same as that for full default. While the model could be extended to handle partial default, it is not clear that there are significant gains from pursuing this. Fourth, we assume away problems of collusion. We have no direct evidence that collusion was not a problem, although reference to it never seems to show up in the documents of the time. If anything, the problem of free-riding when members failed to attend management meetings seemed to be more of a concern.

IV. OPTIMAL CREDIT COOPERATIVES

This section studies optimally designed credit cooperatives, i.e., how the parameters (b,l,r) should be set to foster incentives for monitoring and project selection. We assume that the objective of the co-op is to maximize its ex ante[5] surplus, given by

$$(7) \qquad V \equiv E(\pi) - M(c) - \rho K + (K - b)\delta.$$

This equals the expected project return less monitoring costs and the opportunity cost of capital. The final term is the gain/loss if the opportunity cost of funds is different inside the co-op.

There are two agency problems faced by the co-op. The first is standard: borrowers may not choose surplus maximizing projects. This may be offset by having a monitor who can punish the borrower. However, there is a second agency in having the monitor choose the punishment optimally. The cooperative can specify rules about borrowing outside, liability, and internal interest rates. It cannot, however, directly specify the choice of project or level of monitoring. Thus, it must respect the incentive constraints (4) and (6). An *optimal constitution* for the credit cooperative involves choosing (b,l,r) to maximize ex ante surplus, with π and c determined by (4) and (6).

We begin by considering what happens if first π and c, and then only c, can be chosen directly as features of co-op design. In the first case, $\pi = 1$ and $c = 0$ would be chosen, since safer projects have the highest expected returns and monitoring is costly. Whether internal funds are used depends upon whether $\delta \gtrless 0$.

Other aspects of the co-op's constitution then serve no purpose in affecting its performance.

In the case where c but not π can be chosen, the parameters (b,l,r) can be set to affect project choice. However, since c can be stipulated, it will be chosen to maximize (7) yielding

$$(8) \qquad R'(\pi) \frac{\partial g}{\partial c} - M'(c) = 0.$$

Thus, the marginal value of monitoring, which is the increase in the expected profit project return when c is increased, is set equal to its marginal cost. Some monitoring is now worthwhile to counteract the incentives of borrowers. The level of monitoring implied by (8) is not necessarily optimal in the presence of an agency problem in monitoring since it ignores the effect of (b,l,r) on project choice via $\bar{r}$. However, (8) is a useful benchmark case to which we return below.

Our exploration of the optimal credit cooperative begins by deriving the first-order conditions for (b,l,r). The first-order condition for b is

$$(9) \qquad R'(\pi) \frac{\partial \pi^*}{\partial b} - M'(c) \frac{\partial c^*}{\partial b} - \delta = 0,$$

with equality if $0 < b < K$. There are three terms. The first is the effect on project choice. This has a direct component (operating through $\bar{r}$) and an indirect one operating through the change in c. The second term represents the effect on costs of changing c. The third is an effect whose sign depends upon whether internal or external funds have a higher opportunity cost. The first-order condition for liability choice is

$$(10) \qquad R'(\pi) \frac{\partial \pi^*}{\partial l} - M'(c) \frac{\partial c^*}{\partial l} \geq 0,$$

with equality if $0 \leq l < bR$. This basically parallels the case of b, except for the absence of the final term. The first-order condition for the choice of r is likewise

$$(11) \qquad R'(\pi) \frac{\partial \pi^*}{\partial r} - M'(c) \frac{\partial c^*}{\partial r} \leq 0$$

with equality if $r > (\rho - \delta)/\pi$, since the cooperative must pay at least the opportunity cost of funds if nonborrowing members are willing to lend. Equation (11) again displays the same two basic

terms. We refer to setting $r = (\rho - \delta)/\pi$ and $l = 0$ as the *default options* for these parameters, i.e., to denote situations in which neither of these is set to foster monitoring incentives.

We begin by looking at how the level of c induced by an optimal constitution compares with that given by (8). This is answered in

PROPOSITION 1. The optimally designed co-op generates more monitoring than in the case where c can be directly stipulated. If (b,l,r) are determined optimally, then the monitor chooses a level of c so that the marginal product of monitoring $(R'(\pi)\partial g/\partial c)$ is less than its marginal cost $(M'(c))$.

Proof of Proposition 1. See Appendix B.

Suppose that monitoring were valuable on the margin. Then, since increasing l increases both c and π while reducing $\bar{r}$, it will be set at its maximum possible value. The monitor will then owe the bank the interest independently of whether the project succeeds. At the same time he will keep the whole of $\bar{r}$ which (ex hypothesi) is greater than $E'(\pi)$ which measures the social benefit from monitoring. Thus, the private return to monitoring exceeds the social return.

Proposition 1 is a general result concerning the optimum when a vector (b,l,r) is being optimally set. We would like, however, to understand each separate aspect of co-op design. Our next set of results illustrates how the three features of the co-op design should be optimally chosen.

The first result is on the choice of r and l. Should the cooperative ever set the interest rate on internal funds above their opportunity cost? Proposition 1 suggests an immediate answer. Since c is "too high," and increasing r always reduces π and may sometimes increase c, there is no need to raise r above $(\rho - \delta)/\pi$ unless it will reduce c. Thus, we have

PROPOSITION 2. If internal funds receive more than their opportunity cost, then the marginal effect of an increase in r must be to *reduce* the penalty imposed by the nonborrower.

Proof of Proposition 2. See Appendix B.

The next result concerns the choice between l and r as ways of affecting the choice of c. Since from Proposition 1 we know that reducing c at the margin raises ex ante surplus, we would like to choose parameter values to accomplish this task. We now compare liability and the interest on internal funds as devices to achieve

this. From the previous result the effect at the margin of increasing r is to reduce c and π. Reducing l also reduces both c and π (by raising $\bar{r}$). However, increasing r only reduces c through its effect on $\bar{r}$. Its direct effect is to *increase c*, whereas *both* the direct effect and the indirect effect of reducing l go in the direction of reducing c. Hence, for a given reduction in π, reducing l generates a bigger reduction in c than an increase in $\bar{r}$. As long as the reduction in l is feasible, it is, therefore, a preferred instrument.

PROPOSITION 3. If the co-op pays the nonborrowing member more than his opportunity cost of funds, then liability will be set to zero.

Proof of Proposition 3. See Appendix B.
Our final result concerns the effect of having $\delta < 0$, i.e., a lower opportunity cost of funds inside the co-op. In this case the funds borrowed by the co-op will be entirely from outside.

PROPOSITION 4. If the opportunity cost of funds is greater outside the co-op ($\delta < 0$), then the co-op will not borrow at all from its members, but will use the nonborrowing member as a guarantor (with $l > 0$), thus generating incentives for him to monitor.

Proof of Proposition 4. See Appendix B.
The result says that, if there is a better lending deal outside the co-op, it will pay the monitor to place his funds there. In this case the co-op will generate incentives for the nonborrowing member to commit to punishing the borrower by offering an interest rate above the opportunity cost of funds. (Note that the Proposition does not say anything about the case where $\delta \geq 0$.)

This concludes the formal part of the paper. Our next task is to compare the theoretical predictions of our model with data on the German credit cooperatives in the nineteenth and early twentieth centuries.

V. A TEST

1. Background

German credit cooperatives were founded in the second half of the nineteenth century under the leadership of Hermann Schulze-Delitzsch and Friederich Raiffeisen [1951 (1887)], both of whom viewed credit market problems as significant contributors to

poverty.[6] While these two and other leaders differed on many features of cooperative organization, they agreed that the cooperative's purpose was to make loans to those excluded from banks and other formal institutions: the poor and those lacking collateral. In this they succeeded. The Raiffeisen organization reported that, in 1910, 72 percent of all new loans were backed by personal security while 43 percent of all loans outstanding were for 300 marks or less [Cahill 1913, pp. 108–09]. More generally, the credit cooperatives thrived; by 1909 there were over 14,500 rural credit cooperatives with some 1.4 million members, or about 5.6 cooperatives per 1000 rural Germans. By one estimate nearly one-third of all rural German households at the turn of the twentieth century belonged to a credit cooperative [Grabein 1908, p. 9].[7]

2. The German Debate

German cooperators conducted a lively debate over the best structure for a credit cooperative. This *Systemstreit* focused especially on liability and the payment of dividends. Unlimited liability meant that if a cooperative failed, any unsatisfied creditor could sue any cooperative member for up to the full amount owed to that creditor. Many Schulze-Delitzsch cooperatives adopted limited liability when it became legal in 1889. Dividend policy also divided the cooperative organizations. Raiffeisen-style cooperatives had only nominal shares and paid no dividends to members; any profits in a business year were placed in a permanent reserve fund. Schulze-Delitzsch credit cooperatives, on the other hand, had larger shares and paid dividends to members.

Cooperative advocates used both economic and noneconomic arguments to support their views of the best cooperative structure. Raiffeisen himself stressed a noneconomic interpretation; to him, limited liability and dividends were undesirable because they

6. Verein fur Socialpolitik [1887] is a survey of rural credit conditions in most of Germany. Bonus and Schmidt [1990] is one of the few papers discussing the German cooperatives.
7. 20 marks = 1 pound sterling = $4.86 under the gold-standard exchange rates. An unskilled German laborer would earn in the neighborhood of 10–20 marks per week in the first decade of the twentieth century. Cooperatives data are from the Deutsche Bundesbank [1976, DI, Tables 1.07 and 1.08]. Rural population of Germany for 1910 is defined as persons in places with fewer than 2000 people [Marschalk 1984, Tables 1.3 and 5.5]. We do not discuss two related features of German credit cooperatives. Most cooperatives had accounts at regional cooperative banks that aided in smoothing correlated shocks across cooperatives. In addition, some credit cooperatives were closely allied to purchasing and marketing cooperatives. The latter alliances were the subject of controversy.

undermined the cooperative spirit. Others, however, took the economic view and argued that the basic organizational issues boiled down to practical matters of adapting the cooperative's constitution to local conditions. The Haas federation of cooperatives, which by 1914 had admitted the majority of German credit cooperatives, recognized these practical issues by permitting individual cooperatives to choose their own form of liability. Because of these differences across German cooperatives, we can test our model against cross-sectional variations in cooperative structure. Rigorous econometric tests of these propositions are beyond the scope of this paper. Given the limitations of the published statistical sources, that effort requires work with manuscript sources as outlined in Guinnane [1992a, 1992b]. Here we limit ourselves to a discussion of the relationship between our model's predictions and aggregate information drawn from published studies of cooperatives. The data we discuss below are accurate, and pertain to most if not all credit cooperatives in Germany. Their main defect is that the definitions of the published data do not always correspond precisely to the variables in our model.

3. Comparing the Results with the Data

The model shows that monitoring will be pushed to a point where its marginal value is negative. This result casts different light on one of the proud boasts of the German credit cooperative movement: their extremely low rate of failure. In 1909–1910, years in which there were approximately 15,000 rural credit cooperatives in Germany, none of those with unlimited liability failed, and only three with limited liability failed. Viewed comparatively, private credit institutions were 55 times more likely to fail than were rural credit cooperatives in the period 1895–1905 [Great Britain 1914, p. 315].

For some of the relationships implied by the theory, it will prove helpful to supplement the analytical results from the last section with simulations. We study an example where $R(\pi) = \theta + \beta\pi$ and $M(c) = \alpha c^2/2$. (Appendix C shows that this satisfies necessary regularity conditions for large enough α.) We varied three exogenous variables: the relative costs of inside and outside capital δ, the cost of monitoring α, and a parameter representing the sensitivity of expected return to the borrower's action, β. Note that a higher β represents a higher social return for any given π, thus parameterizing the extent of divergence between the private and the social incentives of the borrower.

Table I reports the main simulation results. Note that worsening the agency problem, either by increasing α or β, leads the cooperative to use its incentive instruments more intensively. For example, as β increases from 0.2 to 0.5, liability increases threefold from 0.2 to 0.6. Increasing π reduces the interest rate paid on internal borrowing significantly. We find that setting the worst available project $\underline{\pi}$ equal to 0.8 or higher is needed to get plausible-looking interest rate premiums. In light of the relatively rare failure rate of the cooperatives, this does not seem unreasonable. We return to other simulation results in the course of discussing specific findings.

The model (Proposition 2) predicts that l and r would never be

TABLE I

SUMMARY OF SIMULATION RESULTS

Exogenous parameters[a]	Function value[b]	Interest premium[c]	Scaled cost of monitoring[d]	π at opt	Optimal values for policy variables		
					l	r[a]	b[e]
$\beta = 0.01$							
$\alpha = 5, \delta = 0.03$	33.91	−0.001	0.92	0.927	0	0.10	1.38
$\alpha = 5$	33.59	0.010	0.96	0.900	0.01	—	2
$\alpha = 5, \underline{\pi} = 0.5$	33.77	0.004	0.95	0.515	0	0.98	1.37
$\beta = 0.2$							
$\alpha = 20$	39.86	0.006	0.02	0.902	0.2	—	2
$\beta = 0.5$							
Baseline	52.31	0.129	0.20	0.910	0.6	—	2
$\delta = 0.03$	54.20	−0.021	2.49	0.936	0	0.09	0.13
$\alpha = 50$	52.25	0.55	0.005	0.903	0.52	—	2
$\beta = 0.8$							
$\alpha = 100$	68.49	0.007	0.10	0.904	0.85	—	2
$\alpha = 100, \delta = 0.03$	72.35	−0.008	6.93	0.911	0	0.12	0.01
$\delta = 0.03$	71.55	−0.037	2.93	0.953	0	0.07	0.19
$\alpha = 100, \delta = 0$	68.49	0.010	0.10	0.904	0.85	—	2

Source. Authors' calculations.

a. Unless otherwise indicated, $\alpha = 20$, $\theta = 1$, $\underline{\pi} = 0.9$, $\rho = 0.05$, $K = 2$, and $\delta = -0.03$.

b. The function maximized is equation (7) with the example provided in subsection V.3. Function value reported as $100 \times \exp(U)$.

c. Scaled monitoring cost $- 100\alpha m^2/2(\theta + \beta\pi)$.

d. Interest premium $= (\rho - \delta)/\pi$.

e. When $b = 2$, r is meaningless.

set above their default values together, implying that unlimited-liability cooperatives would charge lower interest rates to lenders. Published data make it quite difficult to compare l and r on a cooperative-by-cooperative basis. The basic organizational differ-ence does, however, support this prediction. Schulze-Delitzsch cooperatives paid dividends to members while Raiffeisen coopera-tives did not. In fact, Schulze-Delitzsch cooperatives were some-times accused of caring as much about dividends for members as low-cost loans for members. In the polemics of the day this difference was attributed by the Raiffeisen adherents to their desire to keep costs low for borrowers. The model implies some-thing different: given the Raiffeisen commitment to unlimited liability, higher interest rates were redundant as an incentive device. In any case, this finding appears consistent with our theoretical model.

The model, especially Proposition 4, suggests that the sign of δ is an important determinant of whether a liability incentive is used to provide incentives for the monitor, with unlimited liability being more likely when δ is negative.[8] Rural cooperatives were predomi-nantly of the unlimited liability variety. In 1908, 93 percent of all rural credit cooperatives had unlimited liability, compared with 54 percent of urban credit cooperatives [Wygodzinski 1911, p. 60]. Can the sign of δ explain this?

At first sight, the relative isolation of rural cooperatives would seem to imply that δ was positive. Germany's system of *Sparkassen* (state-supported savings institutions) rarely extended beyond cit-ies and towns. Prior to the introduction of a local credit coopera-tive, one authority claimed, savers would keep their money at home, in cash, rather than undertake a long journey to a savings institution [Grabein 1908, pp. 54–55]. Yet, rural credit coopera-tives paid an interest rate *premium* over the *Sparkassen*. One group, for example, paid depositors 3.65 percent on average in 1901, compared with 3.42 percent for the relevant *Sparkassen* [Grabein 1908, p. 59]. While this could be explained by the greater risk associated with cooperative deposits, it suggests that δ is *negative*. Since both rural cooperatives and *Sparkassen* almost never failed to honor their depositors, little of the interest rate premium could plausibly be attributed to failure risk. The possibil-ity that δ was in fact negative is reinforced by the observation that

8. The parameter δ is positive (negative) if the cooperative is a better (worse) place for local savers to keep their funds.

most cooperatives offered a less complete range of services to depositors than would be available in a *Sparkasse* or a commercial bank. Overall, while the limited information available suggests that δ is negative, reaching any firm conclusion on the sign of δ is problematic.

The effect of changing δ on liability choice is investigated in greater detail using the simulation results reported in Table II. As Proposition 4 predicts, a negative value of δ implies positive liability. As we allow the value of δ to climb, the liability level falls. There exists a (typically small) positive value of δ at which the optimal design of the credit cooperative changes quite dramatically. The cooperative switches from using a liability incentive to using internal borrowing with an interest rate incentive, as in the case described in Proposition 2. We pointed out above that reaching a firm conclusion about the sign of δ is quite difficult. These simulations show that the prediction about the design of a credit cooperative in the face of varying δ can be quite dramatic. In favor of our model, this shows how relatively small differences in δ could account for the significant difference between the urban and rural cooperatives. It could also help to explain why approximately half of the Schulze-Delitzsch were unlimited liability, and a few rural cooperatives had limited liability.

TABLE II
SIMULATION RESULTS: THE EFFECT OF δ[a]

	Optimal values for policy variables		
Exogenous parameters[b]	l	r[c]	b
		$\beta = 0.8$	
$\delta = 0.001$	0.98	—	2
$\delta = 0.002$	0.17	1.28	1.21
$\delta = 0.003$	0	1.27	1.05
		$\beta = 0.9$	
$\delta = 0.005$	0	1.24	1.2
$\delta = 0.01$	0	1.24	1
$\delta = 0.002$	1	—	2

Source. Authors' calculations.
a. The function maximized is equation (7) with the example provided in subsection V.3. Function value reported as $100 \times \exp(U)$.
b. Unless otherwise indicated, $\alpha = 20$, $\theta = 1$, $\pi = 0.9$, $\rho = 0.05$, and $K = 2$.
c. When $b = 2$, r is meaningless.

The simulations also reveal that raising α reduces reliance on liability and increases the amount borrowed from within the cooperative. The historical experience is consistent with this prediction about α. Some observers argued that differences between urban and rural environments fully explained the differences between the design of Schulze-Delitzsch and Raiffeisen cooperatives. The Raiffeisen organization reported in 1913 that 80 percent of their credit cooperatives were located in towns of 3000 or fewer persons [Winkler 1933, p. 65]. Urban credit cooperatives tended to be much larger than their rural counterparts. In 1908 the average urban German credit cooperative had 469 members; the average rural cooperative, 94 members. Several urban credit cooperatives were enormous: Munich had one with 2600 members [Wygodzinski 1911, pp. 80–81]. One would expect monitoring costs to be higher in urban environments and in larger cooperatives; cooperative members were dispersed throughout a town or city and less likely to come into day-to-day contact. In addition, the projects for which they borrowed were not so publicly visible as agricultural investments. The Raiffeisen organization insisted on restricting membership to a small region to maximize the availability of information on members. Lower monitoring costs, as the simulations demonstrate, encourage the use of high liabilities.[9] The size of this effect, however, is rather weak. This is consistent with our intuitive understanding of the model. A change in α changes both the private and the social incentives to monitor, but not necessarily the wedge between the private and the social incentives. It is the latter that determines the choice of instruments.

The simulations show that a low β also implies little use of liability while a large β encourages the cooperative to use liability to increase monitoring. For high enough β, we would expect high liability even with a positive δ. If we were to assume that the agency problem is greater in urban areas, then this could also explain the importance of liability incentives there. In fact, the predominantly urban Schulze-Delitzsch co-ops deliberately discouraged the very

9. Some agriculturalists belonged to Schulze-Delitzsch cooperatives, and some town-dwellers belonged to Raiffeisen-style cooperatives, but Schulze-Delitzsch cooperatives were much more likely to be located in large population centers. The membership of the Schulze-Delitzsch cooperatives in 1912 included 28 percent farmers or farm laborers [Great Britain 1914, p. 311]. The greater occupational heterogeneity in a Schulze-Delitzsch cooperative would also imply a larger α, since it would be more difficult for urban workers to screen and monitor agricultural projects and vice versa.

poor from joining. Only a relatively small number of borrowers from these limited-liability cooperatives would have so few assets that disappearing with loan capital would be attractive. Moreover, they emphasized short-term loans, making it more difficult to acquire a large loan intended for a long-term project and then either misusing it or absconding with the money. The rural cooperatives, on the other hand, often made small and long-term loans to very poor individuals, people who might well (in the absence of the cooperative's monitoring) have been tempted to disappear with a loan, or to choose an extremely risky project. On the other hand, the same reasons that made the cost of monitoring higher in urban areas might also make β higher there.

The model further predicts that r and b are used to provide incentives only if δ is positive. This proposition is the most difficult to test from available data. We have already referred to the difficulties of signing δ empirically, and published information does not tell us how much of deposits comes from co-op members. The cooperatives had three basic sources of loan capital: loans from outsiders, loans from insiders (that is, member deposits), and the cooperative's own funds. Published accounts lump together all deposits (member and nonmember alike) and distinguish them only from *eigene Mittel,* the cooperative's own funds formed from entrance fees, share capital, and retained earnings. The more urban Schulze-Delitzsch cooperatives relied relatively more on their own funds for loan capital. In 1908, of the liabilities of the 12,000 credit cooperatives in the Haas organization (primarily rural and unlimited-liability), only about 4 percent was *eigene Mittel.* The comparable figure for the 1000 Schulze-Delitzsch cooperatives was 28 percent [Wygodzinski 1911, pp. 139, 164]. Since the *eigene Mittel* belonged to the members, and loans made from this source were in a sense loans from insiders, the information available tends to suggest that more borrowing from inside went with a lower value of δ, contrary to our prediction.[10]

Of the three main propositions suggested by the theory, we conclude that only one, that liability and interest rate incentives would not be used together, is clearly supported by the data. The other two propositions are not rejected by the data, but they are not unreservedly confirmed.

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10. A long article in *Blätter für Genossenschaftswesen* 1904 (50), the organ of the Schulze-Delitzsch group, criticizes reliance on deposits in the Raiffeisen organization.

4. Extensions

Here, we consider some further features of credit cooperatives that may be important in explaining their design. Unlimited liability can also be used as a signaling device; it may serve to convince lenders that the cooperative was well run [Buchrucher 1905, p. 15]. There is some plausibility to this argument given that the unlimited liability co-ops in Germany tended to have poorer members who might find it important to signal that they were responsible. However the very fact that these people are poor, and have few assets, also tends to lower the credibility of such a signal.

Another explanation of the importance of unlimited liability is based on some cooperatives being poorer than others. We have assumed so far that every co-op has the same ability to borrow from its members, yet poorer co-ops would find this more difficult, necessitating greater use of liability. This is consonant with the poorer co-ops borrowing more from outside and explains why the poorer Raiffeisen co-ops relied on liability, despite being rural. But for poor members the use of liability is strictly limited by lack of assets. Thus, it would seem that poorer co-ops would have no effective way of providing monitoring incentives, implying a higher failure rate. But rural cooperatives had *lower* failure rates than urban cooperatives. Another potential weakness of our model is the absence of risk aversion. However, if people were highly risk averse, this would deter the poor most of all from participating in unlimited liability co-ops, which appears contrary to the evidence.

One assumption that it would be desirable to relax is that the cooperative maximizes total surplus. This assumption permits us to derive tight implications in this first analysis of credit cooperatives, but should be relaxed in further research. It is most natural where co-op members are identical, since then maximizing the total surplus also maximizes the return to each participant. However, member heterogeneity in both wealth and need for funds was a real feature of cooperatives [Guinnane 1992b]. Differences in borrowing probabilities or in wealth would require substantial alterations in our stylized model to maintain to participation by members.

Raiffeisen-type cooperatives, which emphasized high liability, were problematic for sufficiently heterogeneous populations. One observer noted that in some of the limited liability cooperatives in Pomerania, one member might have shares worth 100 marks, while another had many shares totaling 20,000 marks. If the latter bore all responsibility, as they effectively would in an unlimited-

liability structure, then the wealthy would be unlikely to join (quoted in Grabein [1908, p. 13, note 1]). Rural, unlimited-liability cooperatives were in fact relatively uncommon in the Prussian provinces of Saxony and Pomerania, two areas with considerable numbers of very large farms. When the Irish Agricultural Organization Society introduced credit cooperatives into Ireland in 1894, it unfortunately chose to adhere strictly to the Raiffeisen model. Irish credit cooperatives never succeeded, with some observers pointing to the unwillingness of the more prosperous to join an institution in which they would shoulder most of the liability.[11]

VI. CONCLUDING REMARKS

This paper constructs a simple model of an optimal credit cooperative. Using the historical German experience, we have examined some implications of the peer monitoring view of credit cooperatives. We find qualified support for this model in the data. However, there are some features of credit cooperatives that we have not addressed in our work and require some further investigation. Of the extensions that we discussed above, introducing heterogeneity in the cooperative's membership is perhaps the most important, along with building detailed models of the long-term interaction view to compare their predictions with the data.

Apart from the specific task of understanding the design of credit cooperatives, our paper also emphasizes the use of comparative static predictions to explore the organization of nonstandard institutions. We argued that it is not enough for our model to be *consistent* with the existence of credit cooperatives. The way in which the organization adapts to different economic environments must also be as theory would predict. This is a stiffer test of both the theory and the data than is most often used. However, it is a challenge that is worth facing in trying to make sense of the reasons behind different organizational forms.

APPENDIX A

Here we justify some assertions made in the text. First recall that

$$(12) \qquad \pi = h(\bar{r}(\pi,\xi),c)$$

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11. One of the few successful Irish credit cooperatives in the early twentieth century had limited liability. See Guinnane [1994].

from equality in (4) where $\xi \equiv (b,l,r)$. We then write $\pi = g(\xi,c)$. The choice of c satisfies

$$(13) \qquad ((K - b)r + l)\frac{\partial h}{\partial c}(\xi,c) = M'(c),$$

from which $c = f(\xi,\pi)$. A pair (π,c) constitutes an *equilibrium* if $c = f(\xi,\pi)$ and $\pi = g(\xi,c)$. They will be differentiable functions of ξ in the relevant domain if $\partial f/\partial\pi \times \partial g/\partial c < 1$. To calculate the derivatives of these functions, define

$$(14) \qquad \Omega \equiv M'(c)\{E'(\pi) - \bar{r}\}^2 > 0.$$

Then, using (13), we have

$$(15) \qquad \frac{\partial f}{\partial b} = \frac{\{(E'(\pi) - \bar{r})r - (l + (K - b)r)(R - r)\}}{\Omega},$$

$$(16) \qquad \frac{\partial f}{\partial l} = \frac{-\{(E'(\pi) - \bar{r}) - (l + (K - b)r)(1 - \pi)/\pi\}}{\Omega} > 0,$$

and

$$(17) \qquad \frac{\partial f}{\partial r} = \frac{-(K - b)\{(E'(\pi) - \bar{r}) - (l + (K - b)r)\}}{\Omega}.$$

For the function $g(\cdot)$ we use equality in (4) to derive

$$(18) \qquad \frac{\partial g}{\partial c} = \frac{-1}{\{E'(\pi) - \bar{r}\}\{1 - \partial h/\partial\pi\}} > 0,$$

$$(19) \qquad \frac{\partial g}{\partial l} = \frac{-(\pi - \underline{\pi})(1 - \pi)}{\pi\{E'(\pi) - \bar{r}\}\{1 - \partial h/\partial\pi\}} > 0,$$

$$(20) \qquad \frac{\partial g}{\partial b} = \frac{(\pi - \underline{\pi})(R - r)}{\{E'(\pi) - \bar{r}\}\{1 - \partial h/\partial\pi\}},$$

and

$$(21) \qquad \frac{\partial g}{\partial r} = \frac{(\pi - \underline{\pi})(K - b)}{\{E'(\pi) - \bar{r}\}\{1 - \partial h/\partial\pi\}} < 0.$$

APPENDIX B

Proof of Proposition 1. Suppose not. Then $E'(\pi)\partial g/\partial c - M'(c) \geq 0$. It is easy to check that this implies that (10) is strictly

positive for all l and hence that $l = Rb$. In that case $\partial \bar{r}/\partial \pi = 0$, and $\partial g/\partial c = \partial h/\partial c$. From (6) we thus have $M'(c) = (r(K - b) + \rho b)\partial h/\partial c = \bar{r}\partial h/\partial c > E'(\pi)\partial h/\partial c = E'(\pi)\partial g/\partial c$, which is a contradiction.

Proof of Proposition 2. Observe that (11) can be written as

$$(22) \quad \frac{1}{1 - g_c f_\pi} (E'(\pi)(g_r + g_c f_r) - M'(c)(f_r + g_r f_\pi))$$

$$= \frac{1}{1 - g_c f_\pi} (E'(\pi)g_c - M'(c)) \frac{\partial c^*}{\partial r} + E'(\pi)g_r.$$

If this is positive, then since $g_r < 0$ (see 21)), we must have $\partial c^*/\partial r < 0$.

Proof of Proposition 3. The key to the proof is showing that $\partial V/\partial r \geq 0$ implies that $\partial V/\partial l < 0$. First note that

$$(23) \quad \frac{\partial V}{\partial l} \bigg/ \frac{\partial g}{\partial l} = \left\{ E'(\pi) \frac{\partial g}{\partial c} - M'(c) \right\} \left(\frac{\partial f}{\partial l} \bigg/ \frac{\partial g}{\partial l} \right) + \left\{ E'(\pi) - M'(c) \frac{\partial f}{\partial c} \right\}$$

and

$$(24) \quad \frac{\partial V}{\partial r} \bigg/ \frac{\partial g}{\partial r} = \left\{ E'(\pi) \frac{\partial g}{\partial c} - M'(c) \right\} \left(\frac{\partial f}{\partial r} \bigg/ \frac{\partial g}{\partial r} \right) + \left\{ E'(\pi) - M'(c) \frac{\partial f}{\partial c} \right\}.$$

Now from (17) and (21),

$$(25) \quad \frac{\partial f}{\partial r} \bigg/ \frac{\partial g}{\partial r} = \frac{\{(E'(\pi) - \bar{r}) + ((K - b)r + l)\}}{\Omega(\pi - \underline{\pi})(E'(\pi) - \bar{r})(1 - \partial h/\partial \pi)},$$

and from (15) and (19),

$$(26) \quad \frac{\partial f}{\partial l} \bigg/ \frac{\partial g}{\partial l} = \frac{\{(E'(\pi) - \bar{r})[\pi/(1 - \pi)] - ((K - b)r + l)\}}{\Omega(\pi - \underline{\pi})(E'(\pi) - \bar{r})(1 - \partial h/\partial \pi)}.$$

Thus,

$$(27) \quad \frac{\partial f}{\partial l} \bigg/ \frac{\partial g}{\partial l} - \frac{\partial f}{\partial r} \bigg/ \frac{\partial g}{\partial r} = \frac{1/(1 - \pi)}{\Omega(\pi - \underline{\pi})(E'(\pi) - \bar{r})(1 - \partial h/\partial \pi)} > 0,$$

which, since $E'(\pi)\partial g/\partial c - M'(c) < 0$, implies that

$$\frac{\partial V}{\partial r} \bigg/ \frac{\partial g}{\partial r} > \frac{\partial V}{\partial l} \bigg/ \frac{\partial g}{\partial l}.$$

But since $\partial g/\partial r < 0$ and $\partial g/\partial l > 0$, then $\partial V/\partial r \geq 0$ implies that $\partial V/\partial l < 0$, as claimed. But r exceeds the opportunity cost of funds

only if $\partial V/\partial r \geq 0$. Hence in that case we must have $\partial V/\partial l < 0$, which implies that $l = 0$.

Proof of Proposition 4. Since $R \leq \rho/\pi$ (using (1)), then $\delta < 0$ implies that $r > R$, which implies (from (20)) that $\partial g/\partial b > 0$. Next, observe that

$$(28) \quad \frac{\partial V}{\partial b}\bigg/\frac{\partial g}{\partial b} = \left\{ E'(\pi)\frac{\partial g}{\partial c} - M'(c) \right\} \left(\frac{\partial f}{\partial b}\bigg/\frac{\partial g}{\partial b} \right)$$
$$+ \left\{ E'(\pi) - M'(c)\frac{\partial f}{\partial c} \right\} \left(-\delta \bigg/ \frac{\partial g}{\partial b} \right).$$

Now suppose that $l > 0$ and $(K - b) > 0$. Then we must have

$$\frac{\partial V}{\partial b}\bigg/\frac{\partial g}{\partial b} \leq 0 \qquad \text{and} \qquad \frac{\partial V}{\partial l}\bigg/\frac{\partial g}{\partial l} \geq 0.$$

Note that

$$(29) \quad \frac{\partial f}{\partial b}\bigg/\frac{\partial g}{\partial b} = \frac{\{(E'(\pi) - \bar{r})[r/(R - r)] - ((K - b)r + l)\}}{\Omega(\pi - \underline{\pi})(E'(\pi) - \bar{r})(1 - \partial h/\partial \pi)}.$$

Thus,

$$(30) \quad \frac{\partial f}{\partial b}\bigg/\frac{\partial g}{\partial b} - \frac{\partial f}{\partial l}\bigg/\frac{\partial g}{\partial l} = \frac{\{[\pi/(1 - \pi)] + [r/(r - R)]\}}{\Omega(\pi - \underline{\pi})(1 - \partial h/\partial \pi)} < 0.$$

But then since $E'(\pi)\partial g/\partial c - M'(c) < 0$,

$$\frac{\partial V}{\partial l}\bigg/\frac{\partial g}{\partial l} \leq \frac{\partial V}{\partial b}\bigg/\frac{\partial g}{\partial b},$$

implying that $l = 0$. Recall that an alternative way to write the expression for $\partial V/\partial b$ is

$$(31) \quad \frac{\partial V}{\partial b} = \frac{1}{1 - g_c f_\pi}(E'(\pi)g_c - M'(c))\frac{\partial c^*}{\partial b} + E'(\pi)g_b.$$

Since the last two terms here are positive, if $\partial V/\partial b \leq 0$ (required for an optimum with $b < K$), then $\partial c^*/\partial b > 0$ at the optimum. Let (b^*, r^*) be the values of b and r at the optimum (we have already shown that $l^* = 0$). Note that the configuration $b' = K, r = r^*$, and $l = 0$ results in $c = 0$ (there is no incentive to monitor). Yet, at the optimum with $b = b^* < K, c > 0$ and $\partial c^*/\partial b > 0$. So keeping l fixed at 0 and r at r^*, if there is an increase in b from b^* to K, then c must

first rise and then fall. Therefore, there must exist a value of b, call it $\hat{b}$, with $\hat{b} > b^*$, such that the configuration $b = \hat{b}$, $l = 0$, $r = r^*$ generates the same value of c as the social optimum. Since $\hat{b} > b^*$, and $g_b > 0$, the resulting value of π will be higher than that at the suggested optimum. Also since $\delta < 0$, this will also reduce the cost of capital to the cooperative. Thus, the original choice of parameters at $(b^*, r^*, l^* = 0)$ could not have been optimal. This proves that $b = K$ at the optimum and r is also, therefore, effectively redundant. But then we must have $l > 0$ at the optimum as claimed.

APPENDIX C

Here we show that the example yields well-behaved $c(\cdot)$ and $\pi(\cdot)$ functions. For any given value of π, we can determine c from

$$(32) \qquad \alpha c = \frac{l + (K - b)r}{(\rho b - l)/\pi + (K - b)r - \beta} \, .$$

The choice of π is determined from

$$(33) \qquad c = (\pi - \underline{\pi})\{(\rho b - l)/\pi + (K - b)r - \beta\}.$$

Thus, we are looking for a fixed point of the map:

$$(34) \qquad \pi = \underline{\pi} + \frac{l + (K - b)r}{\alpha\{l + (K - b)r - \beta + (\rho b - l)/\pi\}^2} \, .$$

Now at $\pi = \underline{\pi}$, the right-hand side of (34) exceeds the left-hand side. Moreover, the right-hand side of (34) is increasing in π. Thus, we have a fixed point provided that

$$(35) \qquad 1 - \underline{\pi} > \frac{l + (K - b)r}{\alpha\{l + (K - b)r - \beta + (\rho b - l)/\pi\}^2} \, ,$$

which holds if α is large enough. It will be unique if

$$\frac{2[l + (K - b)r](\rho b - l)/\pi}{\alpha\{[l + (K - b)r] - \beta + (\rho b - l)/\pi\}^3} < 1,$$

which also holds for large enough α. Hence, for large enough α, we have a unique fixed point between $\underline{\pi}$ and 1. Thus, π will be a differentiable function of (b, r, l), as required.

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