

10-23-2008

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## Recommended Citation

Oviedo, P. Marcelo and Sikdar, Shiva, "Optimal banking sector recapitalization" (2008). *Economics Working Papers (2002–2016)*. 162.  
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## **Keywords**

financial intermediation, bank recapitalization, banking crises, banking capital

## **Disciplines**

Economics

# IOWA STATE UNIVERSITY

## **Optimal Banking Sector Recapitalization**

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January 2008

Working Paper # 08002

## **Department of Economics Working Papers Series**

**Ames, Iowa 50011**

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# Optimal Banking Sector Recapitalization\*

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October 23, 2008

## Abstract

Government-financed bank restructuring programs, occasionally costing up to 50% of GDP, are commonly used to resolve banking crises. We analyze the Ramsey-optimal paths of bank recapitalization programs that weigh recapitalization benefits and costs under different financing options. In our model bank credit is essential, due to a working capital constraint on firms, and banks are financial intermediaries that borrow from households and lend to firms. A banking crisis produces a disruption of credit and a fall in output equivalent to those in developing countries affected by banking crises. Full recapitalization of the banking system immediately after the crisis is optimal *only if* international credit is available. One-shot recapitalization is *not* optimal with domestically-financed programs, even if the government has access to non-distortionary taxes. The welfare cost of a crisis is substantial: the equivalent permanent decline in the no-crisis steady state consumption ranges between 0.51% and 0.65%, depending on the source of financing the recapitalization program.

JEL classification codes: E44, E62, H21, G21.

Key words: bank recapitalization; banking crises; financial intermediation; banking capital.

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\*We are thankful to Joydeep Bhattacharya, Patrick Honohan, Harvey Lapan, Filippo Occhino and Rajesh Singh for helpful comments. We have also benefited from comments by participants at the 8th Public Economic Theory Meetings, 72nd Midwest Economics Association Meetings and seminar participants at Iowa State University.

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# 1 Introduction

Banking sector problems leading to bank insolvencies have been frequent in recent decades in developed and developing countries alike. Lindgreen et al. (1996) report that, between 1980 and 1996, 133 of the 181 of IMF's member countries have experienced significant banking sector problems, including numerous banking crises. Along the same lines, Caprio and Klingebiel (2003) report that between the late 1970s and 2002, there were 117 systemic banking crises - defined as much or all of the banking capital being exhausted - in 93 countries. The currently unraveling banking crisis only adds to this rather long list.

The macroeconomic consequences of banking crises are well documented. In their study of 36 banking crises in 35 countries between 1980 and 1995, Demüirgüç-Kunt et al. (2006) define a "banking crisis as a period in which segments of the banking system become illiquid or insolvent" and find that banking crises commonly cause sharp declines in output growth rates. Moreover, financial distress helps in propagating the adverse shocks to the real sectors of the economy when banks reduce lending to creditworthy borrowers. Likewise, the harmful macroeconomic consequences of banking sector problems have been identified in the U.S. economic history during periods of banking-sector distress. Romer (1993), for instance, suggests that "... the banking crises of 1931 and later were a crucial cause of the deepening and sustaining of the Great Depression in the United States ...". Nowadays, there is a large consensus that the current meltdown of the world financial system will lead to a worldwide recession whose depth and duration are only to be seen.

The real effects of banking crises are worse for sectors that have very limited alternatives to bank financing, something that applies across the board in developing countries. The evidence in this regard found by Dell'Ariccia et al. (2005) lead them to subscribe to the view that banks need to be supported during distress in order to prevent a vicious circle in which banking distress and economic contraction reinforce each other.

A sound banking system is often considered a public good that is essential for macroeconomic stability, so it is not surprising to see governments get drawn into the costly process of recapitalizing bankrupt banks in the aftermath of a banking crisis. Honohan and Klingebiel (2000) find that in their sample of 40 crisis-countries, governments end up bearing most of the direct costs of the crises<sup>1</sup>. Fiscal resolution costs average about 13% of GDP in general, and 14.3% in developing

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<sup>1</sup>The recapitalization of banks in the United States and Europe currently being undertaken by respective gov-

countries. However, these fiscal costs are, at best, a lower bound on the resources involved in remedying the effects of a banking crisis since actual costs are substantially higher due to indirect methods of government assistance, and the buildup of direct liabilities from state owned banks and of contingent liabilities from deposit and credit guarantees (see Daniel et al., 1997). According to Caprio and Klingebiel (1996), an overall estimate of the amount of resources involved in bank restructuring programs is between 10 and 20% of GDP in most cases and occasionally as much as 40-55% of GDP.

Not only is the expenditure side of the fiscal balance affected by a banking crisis, the revenue side is hit as well. The general slowdown of the economy following a banking crisis substantially reduces tax bases and therefore tax revenues. All in all, a banking crisis is a costly (and recurrent in some countries) phenomenon that produces serious adverse macroeconomic consequences and has enormous negative effects on fiscal balances, mostly because the public-good aspect of a well functioning banking system leads the government to restore the system after a crisis.

This paper characterizes Ramsey-optimal bank restructuring programs from the public finance viewpoint and seeks to answer the following question: *once a government decides to recapitalize a bankrupt banking sector, what is the optimal path of a program that weights the recapitalization benefits and the program's costs?* To the best of our knowledge, this is the first attempt at *formally* analyzing the problem of recapitalizing a bankrupt banking system in the aftermath of a banking crisis that takes into account the fact that the costs of recapitalization depend on the government's sources of funding the program.

To focus on the public finance aspect of the problem, we abstract from the causes of the banking crises and the moral hazard problems arising from government intervention in a financial system. Instead, we analyze the resolution of a banking crisis once it has occurred and the government has already decided to restructure the economy's bankrupt banking system.<sup>2</sup> Thus, instead of focusing on panics or serious liquidity dry-outs, we focus on the aftermath of a banking crisis when a large fraction of the banking capital stock has already been eroded and the banking system is providing just a fraction of the efficient level of financial intermediation. By recapitalizing undercapitalized banks we refer to the injection of banking capital that restores the ability of these banks to intermediate financial credit at an efficient level.

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ernments extends this list.

<sup>2</sup>Although we abstract from these moral hazard problems, it must be said that recapitalizing undercapitalized banks does not necessarily mean maintaining the management nor the ownership of the bank charter.

We conduct our analysis by modeling a perfect foresight economy that is hit by an unforeseen banking crisis. Following the empirical literature, we define a banking crisis as an event in which much or all of the bank capital is depleted (see Caprio and Klingebiel, 2003). We model banks following Cole and Ohanian (2000) and, in our model, the banking sector is a financial intermediary that borrows from households and lends to firms. Bank deposits are the only saving mechanism available to households; banks intermediate these deposits to lend to the firms, which face a working-capital constraint that requires them to pay their wage bill before cashing their sales. Government outlays comprise of a fixed unproductive government consumption and, in the event of a banking crisis, the costs of recapitalizing the banking system. These features would be representative of conditions in developing countries.

The mechanism through which output and employment plummet in the aftermath of a crisis is as follows. A decline in the stock of banking capital leads to a decline in the loan supply. The consequent rise in the interest rate on working-capital loans leads firms to reduce their demand for inputs, which in turn causes a decline in production. Hence, replenishing bank capital raises the volume of financial intermediation, increases loan supply, reduces interest rates, and thereby stimulates output and employment in the aftermath of a crisis.

To characterize efficient programs, we formulate a Ramsey planner's problem in which the government has to choose a bank restructuring program that can be implemented as a competitive equilibrium. The government's objective, in the aftermath of a banking crisis, is to endow the economy with the benefits of a well running banking system but internalizing the direct and indirect resource costs of the recapitalization program. Thus, the optimal program hinges upon the means by which the government funds it. In particular, we characterize the optimal bank restructuring program under three alternative sources of public revenue. In the first case, rebuilding the banking sector can only be financed with distortionary labor taxes. Second, we allow the government to resort to lump-sum taxes to fund the restructuring program. Finally, we rule out lump-sum taxes, but the government has access to international debt markets to finance the recapitalization program.

We find that only when the government has access to international credit, is it optimal to *fully* recapitalize the banking system in the period following the crisis. With domestically-financed recapitalization programs, however, even when non-distortionary taxes are available, it is *not* optimal to recapitalize the banks in one period. Our results contrast those found in the literature

dealing with the microeconomic aspects of bank restructuring policy which, by abstracting from the public finance aspect of the problem, *always* recommends an immediate, full recapitalization of banks to prevent further loss of confidence in the problem-ridden banking system.

To fix ideas about our results, consider the case where the government has access to international debt to fund the bank recapitalization program. The banking system is bankrupt in the initial period and the loss of banking capital submerges the economy into a recession in that period. By borrowing abroad, the government is able to secure the funds necessary to recapitalize the banks, so the economy quickly recovers from the recession in the next period. Moreover, using international debt, the government can also provide subsidies to the households to alleviate the effects of the recession until the banking crisis is resolved in the next period. From then on it is optimal to smooth out the distortionary taxes so that the debt incurred to finance the bank restructuring program is rolled over forever. Thus, with access to international credit, full, one-period recapitalization of the banks is optimal and the government is able to achieve perfect consumption smoothing.

Results are different when the economy lacks access to external credit to finance the recapitalization program and the government has to resort to domestic taxation. Assume first that lump-sum taxes are available. Fully recapitalizing the banks in one period is not optimal because lump-sum taxes, despite being non-distortionary, withdraw large amounts of resources from the private sector which causes a decline in consumption and hence in welfare. Consumption smoothing thus entails that the government replenish the stock of banking capital gradually. When only distortionary labor taxes are available, recapitalization of the bankrupt banking sector is even slower. This is because labor-income taxation, apart from withdrawing resources from consumption, distorts the consumption-leisure choice of the households.

Quantitative results from the numerical solution of the model, calibrated to match basic macroeconomic ratios in developing countries, indicate the following: a banking crisis results in a welfare loss equivalent to a 5.51% permanent decline in the no-crisis steady state consumption if the government does not intervene. When the recapitalization program is financed by labor-income taxes, the economy reaches the new steady state in 23 periods, and the resulting welfare loss is 0.65%. With lump-sum taxes available to the government, convergence to the new steady state occurs in 22 periods, with the welfare loss being reduced to 0.63%. Access to international debt mitigates the above welfare loss to 0.51% reduction in the no-crisis steady state consumption

and the new steady state is reached in two periods.

The rest of the paper is organized as follows. In the next section we present the perfect-foresight, decentralized, general equilibrium model. We formulate the corresponding Ramsey problem in Section 3. Section 4 presents the quantitative results and Section 5 concludes.

## 2 The Model

We model a perfect-foresight economy with four types of agents: households, goods-producing firms, banks and the government. Firms, which along with the banks, are owned by the households, need working capital to pay their wage bill before cashing their output's sale proceeds. Banks intermediate by borrowing savings from households and by lending working capital to the firms. Firms' technology combine capital and labor to produce output, while banks' technology uses deposits and bank capital to produce loans.

To guarantee the consistency of the intertemporal household's deposit decisions with the (essentially) atemporal banks' and firms' optimization problems involving credit, we follow Neumeyer and Perri (2005) to assume that there are two times within each period  $t$ . One at the beginning of the period, denoted by  $t^-$ , and one at the end of the period, denoted by  $t^+$ . We assume that  $t^+$  and  $(t+1)^-$  are arbitrarily close. At  $t^-$  banks accept deposits,  $d_t$ , from the households and use them along with the stock of banking capital,  $A_t$ , to produce loans instantaneously. Firms need to borrow from the banks to fulfill their working capital constraint at  $t^-$ . Labor is hired and paid using loans from the banks at  $t^-$ . Firms use the hired labor and the capital stock to produce the final good which becomes available at  $t^+$ . Firms repay their loans along with interest,  $R_{bt}b_t$ , to the banks at  $t^+$ . Firms' and banks' profits,  $\pi_t^f$  and  $\pi_t^b$  respectively, are distributed to the households, along with the gross interest income,  $R_t d_t$ . The household allocates these resources between consumption,  $c_t$ , and savings, in the form of one-period deposits in the banks,  $d_{t+1}$ . Within each period, the government collects taxes and uses the proceeds to pay for its outlays which include the fixed government expenditure,  $\bar{g}$ , and may also include other transfers related to the recapitalization of the banking system.

## 2.1 Households

The representative household has an infinite life and chooses sequences of consumption, labor supply, and bank deposits,  $\{c_t, h_t, d_{t+1}\}_{t=0}^{\infty}$ , to maximize the following lifetime discounted utility

$$\sum_{t=0}^{\infty} \beta^t U(c_t, l_t) \quad (1)$$

where  $\beta$  is a standard discount factor and  $U$  is a strictly concave, increasing, and differentiable utility index that depends on consumption,  $c_t$ , and leisure,  $l_t$ . The time endowment is normalized to 1, hence labor effort is  $h_t = 1 - l_t$ . The utility maximization problem is subject to a flow budget constraint,

$$c_t + d_{t+1} + T_t \leq (1 - \tau_t)w_t h_t + R_t d_t + [\pi_t^f + \pi_t^b]; \quad t \geq 0 \quad (2)$$

that restricts the household's expenditure to not exceed its income at any time. The sources of income are net labor income, gross return on deposits, and dividends. Net labor income depends on the wage rate,  $w_t$ , the amount of labor supplied,  $h_t$ , and the tax rate on labor income,  $\tau_t$ . Bank deposits,  $d_t$ , are the only savings vehicle available to the household and they are remunerated at the gross rate  $R_t$ . Furthermore, as the household owns all firms and banks in the economy, it collects the respective profits,  $\pi_t^f$  and  $\pi_t^b$ . The household allocates its resources between savings,  $d_{t+1}$ , i.e., deposits payable next period, consumption,  $c_t$ , and the payment of the lump-sum tax,  $T_t$ .

A sequence  $\{c_t, h_t, d_{t+1}\}_{t=0}^{\infty}$  is optimal from the household's standpoint if it satisfies the resource constraint in eq. (2) with equality and if the following conditions hold at  $t \geq 0$ :

$$\frac{U_l(t)}{U_c(t)} = (1 - \tau_t)w_t \quad (3)$$

$$U_c(t) = \beta U_c(t+1)R_{t+1} \quad (4)$$

where  $U_c(t)$  and  $U_l(t)$  are the marginal utilities of consumption and leisure at time  $t$ . Eq. (3) equates the marginal rate of substitution of leisure for consumption to the wage rate net of taxes, and eq. (4) is a standard dynamic efficiency condition for savings that governs the optimal allocation of deposits. The tax on labor income lowers the net wage received by the households, which reduces the consumption-leisure ratio. Thus the substitution effect of a labor tax results in a fall in consumption and labor effort.

## 2.2 Firms and the Working Capital Constraint

The representative firm owns a fixed capital stock,  $\bar{k}$ , which is combined with labor,  $h_t$ , to produce the final good,  $y_t$ , using a constant returns to scale production function:

$$y_t = f(\bar{k}, h_t) \quad (5)$$

The firm faces a working capital constraint on its wage bill: it has to borrow from banks to finance its labor costs before cashing its sales. Hence firms borrow  $b_t (= w_t h_t)$  from the banks. Due to rents accruing to the fixed capital stock, the firm makes positive profits that are distributed to the households. The firm chooses  $h_t$  to maximize its profits,  $\pi_t^f = y_t - R_{bt} w_t h_t$ , taking as given the wage rate,  $w_t$ , and the gross interest rate on its borrowing,  $R_{bt}$ . Optimality requires that:

$$R_{bt} w_t = f_h(\bar{k}, h_t) \quad (6)$$

and linear homogeneity of the production function allows us to write the firm's profit as:

$$\pi_t^f = \bar{k} f_k(\bar{k}, h_t) \quad (7)$$

which is the return to the stock of physical capital.

## 2.3 Banks and Banking Crises

Following Cole and Ohanian (2000), we model the representative bank as follows. The bank accepts one-period deposits,  $d_t$ , from households and uses them along with banking capital to produce loans,  $b_t$ , using a Leontief production function<sup>3</sup>:

$$b_t = \min(\gamma A_t, d_t); \quad \gamma \in (0, \infty) \quad (8)$$

where  $A_t$  is the banking capital stock that is owned by the bank and it is in fixed supply ( $\bar{A}$ ) in the pre-crisis equilibrium. The bank chooses  $d_t$  to maximize its profits,  $\pi_t^b = (R_{bt} - 1)b_t - (R_t - 1)d_t$ ,

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<sup>3</sup>This functional form intends to capture that banking capital serves as a buffer to protect depositors against loan losses. The quantity of banking capital, thus, influences a bank's ability to acquire (uninsured) deposits and hence, affects its lending capacity. Furthermore, given capital adequacy ratio requirements that banks face, there is practically no substitutability between banking capital and other inputs (deposits) in a bank's loan production function.

taking as given the lending rate,  $R_{bt}$ , and the deposit rate,  $R_t$ . The bank's maximization problem leads to the following optimality condition:

$$b_t = d_t = \gamma A_t \tag{9}$$

which equates the volume of loans to that of deposits and to  $\gamma$  times the banking capital stock.

We model a banking crisis by assuming an unanticipated exogenous decrease in the stock of banking capital. This is in keeping with the banking crises documented in Chava and Purnanandam (2006) and the definitions of Caprio and Klingebiel (2003). If a crisis occurs in period  $t^c$ , the stock of banking capital declines from  $A_t = \bar{A}$  during the non-crisis times (i.e.,  $\forall t < t^c$ ), to  $A_{t^c} = \underline{A}$  at the crisis time. It can then be seen from eq. (9) that a crisis that erodes a portion of the banking capital stock results in a decline in the supply of loans. We do not model why nor how the crisis happens<sup>4</sup>; instead, we take the crisis as given and carry out our analysis from period  $t^c$  on to consider the optimal path of banking capital injections.

## 2.4 Government

Regardless of the existence of a crisis or of an ongoing bank recapitalization program, we assume that the government has a constant level of unproductive expenditures,  $\bar{g}$ , which it finances by resorting to lump-sum taxes. This assumption pursues a two-fold goal: it permits matching the normal level of government expenditures to output ratio in developing countries while isolating the effects of financing a bank recapitalization program from that of financing normal government expenditures.

Following what has been observed in countries that have faced banking crises, including the current financial crisis, we assume that the government gets drawn into restructuring the banking sector, although this is shown to be optimal in the model above when the private sector is ruled out from recapitalizing the banks. When a crisis triggers the implementation of a bank recapitalization program, in addition to  $\bar{g}$ , the government has to spend  $x_t$  to inject capital to the banking system<sup>5</sup>. Capital injections make the banking capital stock evolve according to  $A_{t+1} = A_t + x_t$ . We characterize the optimal path of  $x_t$  under alternative source of financing the

<sup>4</sup>See Demirgüç-Kunt and Detragiache (1998) for a discussion of the causes of banking crises.

<sup>5</sup>Although the government does not get equity in the banks in return for these transfers, the return to these injections accrue, implicitly, to the households in the economy in the form of dividends from the banks. Hence, the taxpayers who fund the bank recapitalization program do, in fact, get returns from this recapitalization program.

recapitalization program. Implicit in this formulation of bank capital injections is the assumption that only the government can recapitalize the banks. We take this assumption as an extreme characterization of the difficulties that banks face in issuing equity to recapitalize themselves in the aftermath of a banking crisis.<sup>6</sup>

The general form of the government budget constraint is:

$$\bar{g} + x_t + R^*b_t^g = \tau_t w_t h_t + b_{t+1}^g + T_t \quad (10)$$

where  $b_t^g$  is the time  $t$  stock of international debt issued by the government and  $R^*$  is the gross interest rate on international debt. We will later specialize this constraint according to the funding sources available to the government.

## 2.5 Competitive Equilibrium

A competitive equilibrium is a sequence of allocations,  $\{c_t, h_t, d_{t+1}, A_{t+1}\}_{t=0}^{\infty}$ ; a sequence of prices,  $\{w_t\}_{t=0}^{\infty}$ ; a sequence of interest rates,  $\{R_t, R_{bt}\}_{t=0}^{\infty}$ ; and a sequence of government policies,  $\{x_t, \tau_t, T_t, b_{t+1}^g\}_{t=0}^{\infty}$ , such that: a) households solve their constrained lifetime utility-maximization problem, i.e., eq.'s (2) - (4) hold; b) firms maximize their profits, i.e., eq. (6) and the working capital constraint on the firm hold with equality; c) banks maximize their profits, i.e., eq. (9) holds; d) the government budget constraint is satisfied; and e) the labor, output, deposit, and loan markets clear.

## 3 Optimal Bank Recapitalization Programs: A Ramsey Approach

We characterize alternative bank recapitalization programs that differ in their source of funding by formulating a Ramsey planner's problem. The reason we use this strategy is straightforward: from the precedent equilibrium definition, note that for each bank recapitalization and funding programs, or more generally, for each sequence of government policies, there is a consequent competitive equilibrium. It is then natural to seek the policy that maximizes the household's welfare while satisfying the conditions for a competitive equilibrium, which is precisely what a Ramsey planner does.

It is worth emphasizing that our Ramsey planner's problem is different from the standard

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<sup>6</sup>These difficulties have been apparent in the ongoing financial meltdown around the world.

version where the government has to fund a stream of unproductive government expenditures. In our case the government needs to raise resources to recapitalize the banking system, and given that banking capital is an essential input in the loan production function, the government needs to finance a productive expenditure<sup>7</sup>. At designing the optimal recapitalization path, the planner needs to balance the benefit of recapitalizing the banking system with the costs of raising the resources to do so. On the cost side, apart from withdrawing resources from consumption, the planner must also consider the additional distortions its policy choice introduces in the economy. The benefit of recapitalizing the banks is a better capitalized banking system that is able to extend more loans at a lower interest rate to the firms, which in turn leads to economywide increases in employment, output, and consumption.

We formulate the Ramsey problems corresponding to each of three sources of recapitalization financing: i) the recapitalization is undertaken using revenue from labor-income taxes, ii) lump-sum taxes finance the recapitalization, and iii) the government borrows in international debt markets to recapitalize the banking sector and only distortionary taxes are available to repay the contracted debt.

### 3.1 Labor Income Taxation

Consider the Ramsey planner's problem when the government has to resort to taxation of labor income to finance the recapitalization of the banking system. Here,  $\forall t, T_t = \bar{g}$  and  $b_t^g = 0$ , so the government budget constraint, eq. (10), becomes:

$$x_t = A_{t+1} - A_t = \tau_t w_t h_t \quad (11)$$

The implementability constraint for the Ramsey planner is derived by substituting the household's, firm's and bank's optimality conditions along with the expressions for the profits of firms and banks into the household budget constraint:

$$U_c(t)[c_t + \gamma A_{t+1} + \bar{g} - f(\bar{k}, h_t)] = U_l(t)h_t \quad (12)$$

The resource constraint for the economy is derived by combining the household and the

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<sup>7</sup>Recent papers that consider Ramsey planner's problems with productive public expenditure include Riascos and Végh (2004), and Klein et al. (2007) where government expenditure provides utility to consumers, while Azzimonti et al. (2006) focus on time consistency issues when public capital is an input in private production.

government budget constraints:

$$c_t + \bar{g} + (1 + \gamma)A_{t+1} = (1 + \gamma)A_t + f(\bar{k}, h_t) \quad (13)$$

The Ramsey planner's problem is

$$\max_{\{c_t, h_t, A_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U(c_t, l_t) \quad \text{s.t. (12), and (13)}$$

Let  $\beta^t \mu_t$  be the multiplier on the implementability constraint and  $\beta^t \nu_t$  be the multiplier on the resource constraint. Assuming  $U_{lc}(\cdot) = U_{cl}(\cdot) = 0$ , the optimality conditions are the implementability and resource constraints, eq.'s (12) and (13), along with the following:

$$U_c(t) = \mu_t [U_c(t) + U_{cc}(t) \{c_t + \gamma A_{t+1} + \bar{g} - f(\bar{k}, h_t)\}] + \nu_t \quad (14)$$

$$U_l(t) = \mu_t [U_l(t) - U_{ll}(t) h_t + U_c(t) f_h(\bar{k}, h_t)] + \nu_t f_h(\bar{k}, h_t) \quad (15)$$

$$\mu_t U_c(t) \gamma + \nu_t (1 + \gamma) = \beta \nu_{t+1} (1 + \gamma) \quad (16)$$

where eq.'s (14), (15), and (16) are the first order conditions with respect to  $c_t$ ,  $h_t$ , and  $A_{t+1}$ , respectively.

It in this version of the Ramsey planner's problem the government incorporates in its computation of the cost of recapitalizing banks the fact that the tax on labor income distorts the consumption-leisure choice. This cost component disappears when the government has access to lump-sum taxes although the household still needs to give up a significant fraction of its consumption to direct resources towards recapitalization of banks.

### 3.2 Lump-sum Taxes

When the planner has access to lump-sum taxes to finance the recapitalization program but the economy is excluded from international debt markets,  $b_t^g = \tau_t = 0$ ; in this case, the government budget constraint can be written as:

$$\bar{g} + A_{t+1} - A_t = T_t \quad (17)$$

where it is understood that absent any recapitalization program,  $T_t = \bar{g}$ . The household budget constraint, eq. (2), is now

$$c_t + d_{t+1} + T_t \leq w_t h_t + R_t d_t + [\pi_t^f + \pi_t^b]; \quad t \geq 0 \quad (18)$$

In a standard Ramsey problem, when the planner has access to lump-sum taxes, and there are no other distortions in the economy, the solution involves maximizing the household's objective function subject to the economywide resource constraint. In our case, however, the working capital constraint acts as another distortion in the economy that requires imposing the following implementability constraint on the Ramsey planner's problem:

$$U_c(t)[c_t + (1 + \gamma)A_{t+1} + \bar{g} - f(\bar{k}, h_t) - A_t] = U_l(t)h_t \quad (19)$$

This constraint arises from substituting into the household's budget constraint, eq. (18), the profit functions for the firms and banks, the household and bank optimality conditions, and the value of the government capital injections. The resource constraint for the economy is the same as before, and is repeated here for convenience:

$$c_t + \bar{g} + (1 + \gamma)A_{t+1} = (1 + \gamma)A_t + f(\bar{k}, h_t) \quad (20)$$

The Ramsey planner's problem is

$$\max_{\{c_t, h_t, A_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U(c_t, l_t) \quad \text{s.t. (19), and (20)}$$

Let  $\beta^t \mu_t$  and  $\beta^t \nu_t$  be the multipliers on the implementability constraint and the resource constraint, respectively. Under the assumption that  $U_{lc}(\cdot) = U_{cl}(\cdot) = 0$ , optimality requires satisfying the implementability and the resource constraints, eq.'s (19) and (20), as well as the following conditions:

$$U_c(t) = \mu_t[U_c(t) + U_{cc}(t)\{c_t + (1 + \gamma)A_{t+1} + \bar{g} - f(\bar{k}, h_t) - A_t\}] + \nu_t \quad (21)$$

$$U_l(t) = \mu_t[U_l(t) - U_{ll}(t)h_t + U_c(t)f_h(\bar{k}, h_t)] + \nu_t f_h(\bar{k}, h_t) \quad (22)$$

$$\mu_t U_c(t)(1 + \gamma) + \nu_t(1 + \gamma) = \beta \mu_{t+1} U_c(t+1) + \beta \nu_{t+1}(1 + \gamma) \quad (23)$$

where eq.'s (21), (22), and (23) are the first order conditions with respect to  $c_t$ ,  $h_t$ , and  $A_{t+1}$ , respectively.

Although the taxes are non-distortionary, the recapitalization program involves withdrawing resources that, otherwise, would be allocated to consumption. The planner needs to balance the cost of the current reduction in consumption with the current and future benefits of a better capitalized banking system and this characterizes the optimal recapitalization path.

### 3.3 Government Access to International Debt

When the government has access to international debt and lump-sum taxes are available only to fund the constant level of government expenditures,  $\bar{g}$ , the resource constraint for the economy is the following:

$$c_t + \bar{g} + (1 + \gamma)A_{t+1} + R^*b_t^g = (1 + \gamma)A_t + f(\bar{k}, h_t) + b_{t+1}^g \quad (24)$$

The implementability constraint in this case is:

$$U_c(t)[c_t + \gamma A_{t+1} + \bar{g} - f(\bar{k}, h_t)] = U_l(t)h_t \quad (25)$$

Thus, the Ramsey planner's problem, when the government has access to international debt, is

$$\max_{\{c_t, h_t, A_{t+1}, b_{t+1}^g\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U(c_t, h_t) \quad \text{s.t. (24), and (25)}$$

As before, let  $\beta^t \mu_t$  be the multiplier on the implementability constraint and  $\beta^t \nu_t$  be the multiplier on the resource constraint, and assume that  $U_{lc}(\cdot) = U_{cl}(\cdot) = 0$ . Optimality now requires satisfying the constraints (24) and (25) and the following conditions:

$$U_c(t) = \mu_t[U_c(t) + U_{cc}(t)\{c_t + \gamma A_{t+1} + \bar{g} - f(\bar{k}, h_t)\}] + \nu_t \quad (26)$$

$$U_l(t) = \mu_t[U_l(t) - U_{ll}(t)h_t + U_c(t)f_h(\bar{k}, h_t)] + \nu_t f_h(\bar{k}, h_t) \quad (27)$$

$$\mu_t U_c(t) \gamma + \nu_t (1 + \gamma) = \beta \nu_{t+1} (1 + \gamma) \quad (28)$$

$$\nu_t = \beta \nu_{t+1} R^* \quad (29)$$

where eq.'s (26), (27) (28), and (29) are the first order conditions with respect to  $c_t$ ,  $h_t$ ,  $A_{t+1}$ , and

$b_{t+1}^g$ , respectively.

When the planner weighs the benefits and costs of the banks' recapitalization program, he knows that by borrowing from international debt markets, he can secure the funds necessary to recapitalize the banks, and thereby overcome the need of withdrawing all the required resources from consumption. The cost of this strategy is, however, that in the future, the repayment of the debt incurred to recapitalize the banks will require resorting to distortionary labor-income taxes.

## 4 Quantitative Results

In this section we analyze the quantitative implications of a banking crisis, provide the post-crisis transition paths and discuss the welfare effects of government intervention in each of the three considered sources of resources to recapitalize the banks.

### 4.1 Functional Forms and Parameters

To solve the model numerically we assume the following functional forms. The utility function is separable in consumption and leisure:

$$U(c_t, l_t) = \ln c_t + \theta \ln l_t$$

and the production function is Cobb Douglas:

$$y_t = B\bar{k}^\alpha h_t^{1-\alpha}, \quad \alpha \in (0, 1)$$

The baseline parameter values, which are shown in Table 1, are chosen to be representative of the main macroeconomic and banking conditions in developing countries. The annual net rate of interest on international debt is set at 5%. The household discount factor is set equal to  $1/R^*$ , which gives  $\beta = 0.9879$ . The parameter,  $\theta$ , that determines the share of leisure in the household utility function is set to 1.5, so that work effort is approximately 1/3 of the total time endowment. Following the standard in the literature, the share of physical capital in production of the final good,  $\alpha$ , is set at 1/3. The capital stock,  $\bar{k}$ , and the productivity parameter,  $B$ , are set such that the capital-output ratio, on annual basis, is about 2. The banking capital to deposit ratio in the loan production function is set at 1/10, i.e.,  $\gamma = 10$ , although we later compare the welfare effects

for different values of  $\gamma$ . The fixed component of government outlays,  $\bar{g}$ , is set equal to 2, so that the steady-state government consumption is equal to about 14% of output, as reported by the United Nations for developing countries<sup>8</sup>. The initial steady state level of banking capital,  $\bar{A}$ , is calibrated to match an annual net interest rate on loans of 8.5%, which generates  $\bar{A} = 0.9222$ . One period in the model is interpreted as one quarter.

## 4.2 Transition Dynamics

The timing of events is as follows: at the beginning of period 0 the economy is in steady state and at the end of that period the economy is hit by a banking crisis, hence  $t^c = 0^+$ ; in this same time period, the government initiates its optimal bank recapitalization program. In the empirical literature, a banking crisis is defined as much or all of the banking capital being exhausted (see, for instance, Caprio and Klingebiel, 2003). Taking an approximate mid-point, we discuss the results for a 50% decline in banking capital under the three financing methods.

Figure 1 plots the transitional dynamics induced by the banking crisis and the subsequent government intervention for the three sources of financing discussed above. Given the Leontief structure of the bank-loan production technology, deposits and bank loans follow the same path as banking capital. Also, given the fixed physical capital stock, the path of employment and output are similar.

Consider first the case where the recapitalization is financed by labor-income taxes. In the first period, which is the period of unraveling of the banking crisis, the low stock of bank capital constrains the credit that banks can extend to the firms, which in turn reduces employment and output. Recapitalizing the banks requires a high tax on labor income, which decreases labor supply via the substitution effect, adding another negative effect on labor and output. All in all, consumption declines. The maximum amount of banking capital injections occurs during the first period because the marginal benefit of increasing the stock of banking capital is at its highest level. As the stock of banking capital increases, the marginal benefit of further injections declines. From the second period onward, as the amount of injections decline, so does the tax rate on labor income. Due to the increasing banking capital stock, and hence bank loans, firms are able to borrow and produce more, so the economy starts recovering from the recession caused

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<sup>8</sup>See the United Nations Online Network in Public Administration and Finance data on government consumption as a percentage of GDP in developing countries. See <http://unpan1.un.org/intradoc/groups/public/documents/un/unpan014054.pdf>.

by the banking crisis. Owing to the high resource cost and the distortionary nature of financing the recapitalization program, the optimal recapitalization path is a gradual one.

Consider now the case where lump-sum taxes are available; this is equivalent to the government issuing domestic bonds to pay for the recapitalization program and having access to taxes on the rents accruing to the stocks of capital. On impact, employment, consumption and output decline as the economy responds to the high interest rate on working-capital loans. Since the resources for recapitalization are raised using non-distortionary methods, employment, and hence output, fall less than in the case of distortionary taxes. Although the method of taxation is non-distortionary, consumption smoothing entails a gradual recapitalization path due to the large amount of resources involved. Again, the amount of injections decline over time due to the declining marginal benefit of these injections as the stock of banking capital increases.

When the government has access to international lending, even if the only taxes available are distortionary, the optimal recapitalization is undertaken in one shot and, at the same time, the government is able to smooth consumption completely by borrowing from abroad. Banking capital, and hence bank loans, reach their new steady state level in period 2, while consumption and employment (hence, output) adjust to their new steady state levels in period 1 itself. Although the banking capital stock, and hence the amount of bank loans, is low and the firms are working-capital constrained, the government borrows from international debt markets to subsidize employment in period 1. Due to this, households are willing to supply labor to the firms even at a low gross wage rate,  $w_t$ . Hence, even with a low banking capital stock in period 1, due to the subsidy to labor income, consumption, employment and output are at their new steady-state levels.

Table 2 reports the steady state levels of banking capital, output and consumption. Given the real resource cost of increasing the stock of banking capital, optimality dictates that the marginal cost of financing the bank recapitalization be equated to the marginal benefit of an extra unit of banking capital. When labor-income taxes finance the recapitalization program, apart from having large resource costs, these taxes further distort the economy. With access to lump-sum taxes, the government is able to avoid the distortions caused by the labor-income taxes, but the resources for recapitalization still need to be financed domestically. Only when borrowing from international debt markets is allowed, can the government completely spread out the recapitalization costs over time. Hence, the steady state levels of banking capital, deposits,

loans, employment and output are the highest when there is access to international debt markets, followed by the case of non-distortionary taxes. However, steady state consumption is the lowest with access to international debt, in spite of employment and output being the highest: this is because part of the output is used to pay interest on the country's debt obligations, which in turn requires the households to work more.

### 4.3 Welfare Effects

We compute a number of measures of the welfare effects of a banking crisis (for the different sources of financing) to highlight different aspects of the welfare costs of a crisis. In all cases the no-crisis equilibrium is the benchmark. First, following Lucas (1987), we define the net welfare effects of a banking crisis,  $\lambda_1$ , as the permanent, constant decrease in the no-crisis steady state consumption,  $\bar{c}$ , for  $t = 0, 1, \dots, \infty$ , that leaves households indifferent between the lifetime utility obtained in the no-crisis equilibrium and lifetime utility under the crisis equilibria, inclusive of the transitional dynamics of consumption,  $c_t$ , and leisure,  $l_t$ :

$$\sum_{t=1}^{\infty} \beta^{t-1} [\ln \{(1 - \lambda_1)\bar{c}\} + \theta \ln \bar{l}] = \sum_{t=1}^{\infty} \beta^{t-1} [\ln c_t + \theta \ln l_t] \quad (30)$$

where  $\bar{l}$  is the no-crisis steady state leisure.

While the post-crisis consumption is lower than the no-crisis consumption, the post-crisis employment is always lower than the pre-crisis level. In computing welfare, this drop in employment (increase in leisure) compensates, to some extent, for the lower consumption. To highlight the effect of lower consumption alone, on welfare, we also compute the above welfare effects holding leisure fixed at the pre-crisis steady state level. Thus we define the welfare measure,  $\lambda_2$ , as:

$$\sum_{t=1}^{\infty} \beta^{t-1} [\ln \{(1 - \lambda_2)\bar{c}\} + \theta \ln \bar{l}] = \sum_{t=1}^{\infty} \beta^{t-1} [\ln c_t + \theta \ln \bar{l}] \quad (31)$$

In all cases, the welfare loss computed using our second measure is higher than the one using the first measure because in both methods the consumption profile is the same, given the financing method, but in the second measure employment (leisure) is higher (lower), which reduces the crisis utility level.

To highlight the fact that the transitional costs of a bank recapitalization program, due to decline in consumption, are more severe than the lifetime cost of the crisis, we compute the welfare

loss arising purely from the transitional dynamics of the movement to the post-crisis steady state, under different programs. Note that the times of convergence to the new steady states,  $t^{ss}$ , are different for the different financing methods, reflecting the difference in distortions under different recapitalization programs. We characterize welfare loss as the equivalent permanent reduction in the no-crisis steady state consumption, defining  $\lambda_3$  such that:

$$\sum_{t=1}^{t^{ss}} \beta^{t-1} [\ln \{(1 - \lambda_3)\bar{c}\} + \theta \ln \bar{l}] = \sum_{t=1}^{t^{ss}} \beta^{t-1} [\ln c_t + \theta \ln l_t] \quad (32)$$

Finally, to characterize the effect of lower consumption alone on welfare, in computing the welfare loss induced by the transitional dynamics of a bank restructuring program, we hold leisure fixed at the no-crisis steady state level, and define  $\lambda_4$  to satisfy:

$$\sum_{t=1}^{t^{ss}} \beta^{t-1} [\ln \{(1 - \lambda_4)\bar{c}\} + \theta \ln \bar{l}] = \sum_{t=1}^{t^{ss}} \beta^{t-1} [\ln c_t + \theta \ln \bar{l}] \quad (33)$$

The results for the welfare comparisons are presented in Table 3. We discuss these results for our baseline calibration of a banking capital to deposit ratio of 1/10, i.e.,  $\gamma = 10$ , and we use other values of  $\gamma$  for sensitivity analysis. If the government does not recapitalize the banking system in the aftermath of a crisis and the banking capital stock stays at the crisis level infinitely, then the welfare loss is a decline of 5.51% in the no-crisis steady state consumption using our first measure and 22.08% using the second measure. Recall that the reason for the higher value of welfare loss using the second measure is that, while consumption is at the crisis level, we hold employment (leisure) fixed at the high (low) no-crisis level.

The net welfare loss of a crisis with recapitalization financed by distortionary taxes are 0.65% and 1.42% of the no-crisis consumption using the first and second measures, respectively. The welfare loss purely due to the transitional dynamics involved in the movement to the new steady state is 2.69% of the no-crisis consumption, and is higher at 4.46% if employment (leisure) is held constant at the no-crisis level.

Financing the recapitalization with non-distortionary taxes results in a welfare loss of 0.63% (1.35%) of the no-crisis consumption using our first (second) measure. The welfare loss is to the order of 2.74% due to the transitional dynamics alone, and it is 4.35% if we also hold employment fixed at the no-crisis level.

Access to international debt eases the welfare cost of a banking crisis considerably, and the

welfare loss of a banking crisis is 0.51% of steady state consumption using our first and third measures, while it is 0.72% using the second and fourth measures. The lifetime and transition measures coincide in the case of international debt access because the government, by borrowing from international markets, is able to achieve intertemporal smoothing, and consumption and employment jump to the new steady state values in period 1 itself, while banking capital reaches the new steady state in period 2.

Apart from the welfare effects in the benchmark case, we also compute the above welfare measures for other values of the banking capital to deposit ratio. As shown in Table 3, the welfare losses due to a banking crisis, given the method of financing of the recapitalization program, is increasing (decreasing) in the banking capital-deposit ratio ( $\gamma$ ). Figure 2 plots the welfare costs of banking crises, using measure 1, for different values of  $\gamma$ . As  $\gamma$  increases, i.e., as the banking capital to deposit ratio in the economy declines, the pre-crisis steady state banking capital stock declines. This is because, given the other parameters, the amount of banking capital required to produce the same amount of loans declines. Hence, the welfare loss due to a crisis, given the recapitalization program, declines because amount of resources required for the recapitalization program decreases with the decline in the initial loss of banking capital.

## 5 Concluding Remarks

Banking sector crises, which have been prevalent in both developing and developed countries, have presented a stiff challenge to policy makers and continue to do so. Given the public-good aspect of a well running financial system, governments almost invariably end up bearing the burden of financing the restructuring programs necessary to recapitalize a bankrupt banking system. The high fiscal cost of these programs warrants careful analysis of the financing options used by the government.

In this paper we undertook a first attempt at examining the public-finance aspect of the government's recapitalization of a bankrupt banking sector in a dynamic general equilibrium setting. We formulate the Ramsey planner's problems under three different scenarios: recapitalizations financed with distortionary taxes, with non-distortionary taxes and by borrowing from international debt markets. The Ramsey problems were solved numerically and the welfare costs of a banking crisis were found to be substantial.

The post restructuring levels of banking capital are different under the three regimes, reflecting

the difference in distortions due to the different financing options of the recapitalization program. It has often been suggested that the government should restructure the banking system in one shot, but our analysis of the Ramsey planner's problems shows that optimality requires a gradual approach unless the economy can borrow from international markets. This is because the high resource cost typically involved in bank a restructuring program should be spread out over time to minimize the distortions introduced in funding the program. This highlights the importance of having access to international debt markets during period of financial distress; furthermore, the results discussed here may also justify why under some circumstances it might be highly convenient to have international organizations extending emergency financing to developing countries hit by banking crises. This financing could alleviate the effects of a banking crisis and avoid a rather painful and long-drawn adjustment process in the post-crisis scenario.

We have not considered the moral hazard problems arising from the government intervention in financial markets, nor have we incorporated the different methods used for recapitalization<sup>9</sup>, which can have different effects on the government budget. These issues are important and present avenues for future research. Another possible avenue for future research is the explicit modeling of why private agents do not accumulate banking capital, that necessitates government intervention.

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<sup>9</sup>For details on the latter, see Daniel et al. (1997).

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**Table 1: Baseline Parameter Values**

Parameters		Values
$\beta$	Discount factor	0.988
$\theta$	Leisure share in utility	1.5
$B$	Productivity parameter	6
$\bar{k}$	Physical capital stock	115
$\alpha$	Capital's share in output	1/3
$\gamma$	Ratio of deposits to banking capital	10
$\bar{g}$	Fixed government consumption	2
$R^*$	Quarterly world interest rate	1.012

**Table 2: Steady State Values under Baseline Parameters**

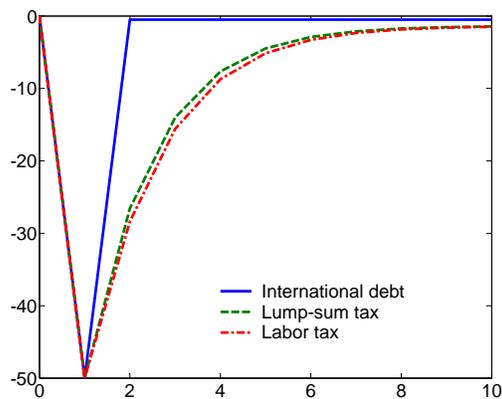
Variable	Pre-crisis	Post-crisis			
		No intervention	Labor tax	Lump-sum Tax	International Debt
$A$	0.922	0.461	0.910	0.910	0.918
$y$	14.118	11.443	14.062	14.063	14.091
$c$	12.118	9.443	12.062	12.063	12.030
$h$	0.337	0.246	0.335	0.335	0.336

Notes: The steady state levels of the variables are different for the different programs reflecting the difference in distortions due to the different financing options of the recapitalization programs. For the time period in which the economy converges to the new steady state, under different financing methods, see Table 3.

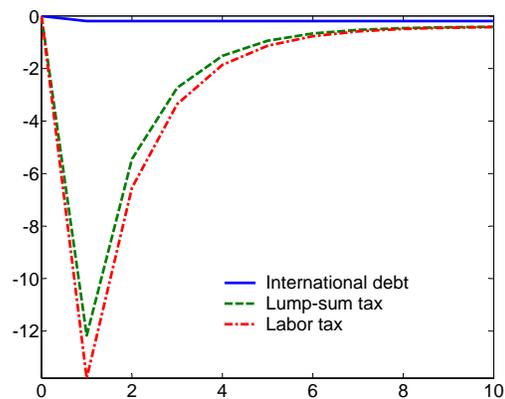
**Table 3: Welfare Effects of Banking Crises  
(50% decline in banking capital)**

$\gamma$	1	5	<b>10</b>	15	20
<b>Period of convergence to new steady state (<math>t^{ss}</math>)</b>					
Labor Tax	44	27	<b>23</b>	23	22
Lump-sum Tax	34	25	<b>22</b>	21	22
International Debt	2	2	<b>2</b>	2	2
<b>Welfare Effects: <math>\lambda_i</math> (in percentages)</b>					
<b>Measure 1</b>					
$\sum_{t=1}^{\infty} \beta^{t-1} [\ln \{(1 - \lambda_1)\bar{c}\} + \theta \ln \bar{l}] = \sum_{t=1}^{\infty} \beta^{t-1} [\ln c_t + \theta \ln l_t]$					
No Intervention	5.51	5.51	<b>5.51</b>	5.51	5.51
Labor Tax	1.19	0.71	<b>0.65</b>	0.63	0.62
Lump-sum Tax	1.07	0.68	<b>0.63</b>	0.62	0.61
International Debt	0.91	0.55	<b>0.51</b>	0.49	0.49
<b>Measure 2</b>					
$\sum_{t=1}^{\infty} \beta^{t-1} [\ln \{(1 - \lambda_2)\bar{c}\} + \theta \ln \bar{l}] = \sum_{t=1}^{\infty} \beta^{t-1} [\ln c_t + \theta \ln \bar{l}]$					
No Intervention	22.08	22.08	<b>22.08</b>	22.08	22.08
Labor Tax	3.46	1.65	<b>1.42</b>	1.37	1.30
Lump-sum Tax	2.87	1.53	<b>1.35</b>	1.34	1.26
International Debt	2.06	0.88	<b>0.72</b>	0.67	0.65
<b>Measure 3</b>					
$\sum_{t=1}^{t^{ss}} \beta^{t-1} [\ln \{(1 - \lambda_3)\bar{c}\} + \theta \ln \bar{l}] = \sum_{t=1}^{t^{ss}} \beta^{t-1} [\ln c_t + \theta \ln l_t]$					
Labor Tax	2.81	2.55	<b>2.69</b>	2.61	2.66
Lump-sum Tax	3.08	2.63	<b>2.74</b>	2.79	2.64
International Debt	0.91	0.55	<b>0.51</b>	0.49	0.49
<b>Measure 4</b>					
$\sum_{t=1}^{t^{ss}} \beta^{t-1} [\ln \{(1 - \lambda_4)\bar{c}\} + \theta \ln \bar{l}] = \sum_{t=1}^{t^{ss}} \beta^{t-1} [\ln c_t + \theta \ln \bar{l}]$					
Labor Tax	6.10	4.46	<b>4.46</b>	4.41	4.32
Lump-sum Tax	5.43	4.25	<b>4.35</b>	4.61	4.18
International Debt	2.06	0.88	<b>0.72</b>	0.67	0.65

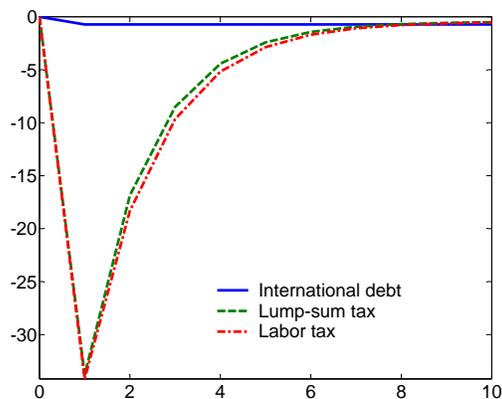
Notes: The no-crisis case is the benchmark for these welfare comparisons.  $\gamma$  is the deposit to banking capital ratio in the economy;  $\bar{c}$  and  $\bar{l}$  are the no-crisis steady state consumption and leisure levels;  $c_t$  and  $l_t$  are consumption and leisure in the crisis equilibrium. The measures of the welfare loss of a banking crisis are defined as the permanent, constant percentage declines in the no-crisis steady state consumption that leave households indifferent between the no-crisis equilibrium and the crisis equilibria, i.e., the  $\lambda_i$ 's satisfy the respective equations.



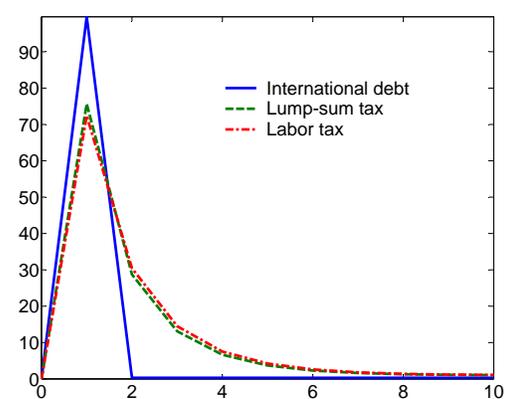
(a) Banking Capital



(b) Output



(c) Consumption



(d) Interest rate on loans

Figure 1: Dynamics in the Aftermath of a Banking Crisis under the Three Recapitalization Programs.

Notes: A banking crisis, that erodes 50% of the banking capital stock, occurs in period 0; from period 1, the government initiates its optimal recapitalization program. All values in the above graphs are % deviations from the pre-crisis steady state.

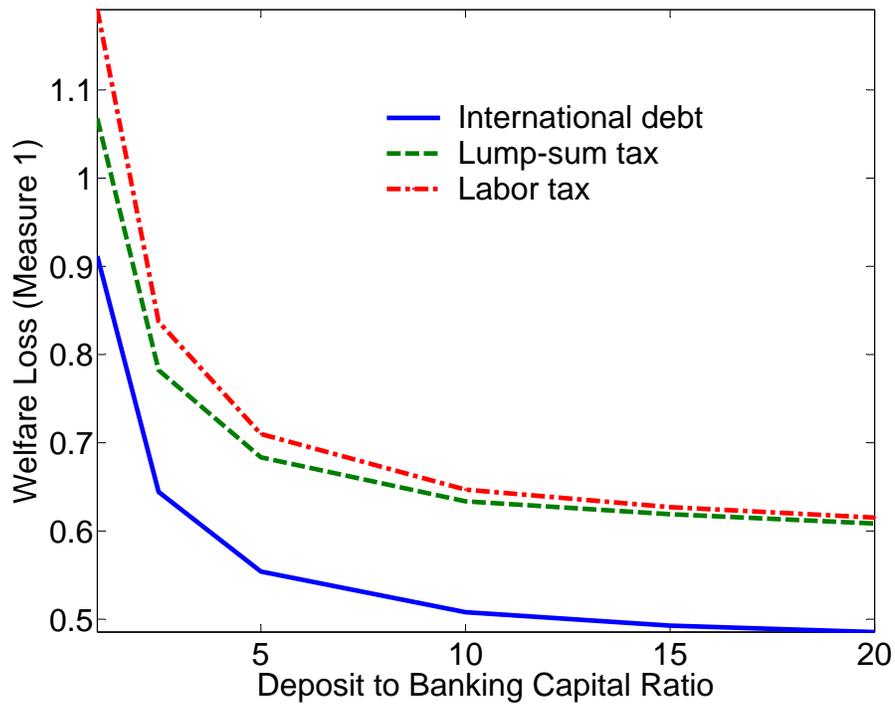


Figure 2: Welfare Costs of Banking Crises.

Notes: The no-crisis equilibrium is the benchmark for these welfare costs. All values in the graph are for welfare measure 1 where  $\lambda_1$  is the permanent, constant percentage decrease in the no-crisis steady state consumption,  $\bar{c}$ , given the no-crisis leisure ( $\bar{l}$ ), for  $t = 0, 1, \dots, \infty$ , that leaves households indifferent between the lifetime utility obtained in the no-crisis equilibrium and lifetime utility under the crisis equilibria, inclusive of the transitional dynamics of consumption,  $c_t$ , and leisure,  $l_t$ , i.e.,  $\sum_{t=1}^{\infty} \beta^{t-1} [\ln \{(1 - \lambda_1)\bar{c}\} + \theta \ln \bar{l}] = \sum_{t=1}^{\infty} \beta^{t-1} [\ln c_t + \theta \ln l_t]$ .