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# Liquidity Constraints and Tax Policy in Small Open Economies

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## Abstract

State-contingent tax policy can generate stabilization gains if an economy is subject to occasionally binding financial constraints. The aim of this paper is to assess whether that claim can be supported in a small open economy real business cycle model with liquidity constraints on the consumer side. In the model, the domestic current account deficit is limited by domestic output such that the ability of consumers to self-insure against productivity risks is restricted. The model is calibrated to Argentine data and solved with standard perturbation methods, using a penalty function approach to account for the non-linear current account restriction. The results show that the presence of liquidity constraints leads to volatile and procyclical consumption spending consistent with the data. In this environment, a government can provide some of the missing insurance to consumers by cutting tax rates on labor income in low-productivity states and vice versa. This type of policy raises domestic liquidity through higher output when necessary, which eases the current account restriction and smoothens out consumption.

*Keywords:* Small open economy models; Real business cycles; Financial frictions; Liquidity constraints; Limited self-insurance; State-contingent tax policy

*JEL classification:* E32; E44; E62; F41

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# 1 Introduction

Financial frictions matter for business cycle analysis. This fact has been clear long before the recent subprime meltdown. Several emerging market economies have been hit by economic crises in the past – Mexico in 1994, Asia in 1997, Brazil and Argentina in 1999 – and financial factors were often considered an important contributing factor to the severity of these crises. However, standard small open economy business cycle models feature non-distorted financial markets. In these models, domestic agents can smooth their consumption by borrowing any desired amount of an internationally traded asset at a fixed interest rate. That is, a large adverse shock can in principle be absorbed by running a large current account deficit. This feature of standard models is counterfactual, which may have problematic policy implications. For instance, optimal fiscal policy in a frictionless environment is characterized by labor tax smoothing. Tax rates should be held steady over time in order to minimize intertemporal tax distortions. In an environment with imperfect capital markets, such policy predictions may change.

The main objective of this paper is to analyze the scope of cyclical labor tax policy in a small open economy real business cycle (RBC) model with distorted financial markets. In the model, occasionally binding liquidity constraints on the consumer side limit the possibilities for domestic consumption smoothing: the maximum current account deficit is limited by a fraction of domestic output. The model is calibrated to Argentine data, and a penalty function approach is used to solve the model with standard local approximation (perturbation) methods. With respect to the specification of fiscal policy, a simple tax feedback rule with a constant labor income tax rate plus a feedback from productivity shocks is considered. The rule is parameterized and the feedback coefficient that maximizes consumer welfare is determined numerically.

I show that the presence of financial constraints provides a rationale for procyclical labor income taxes, that is, tax rates should be cut in low-productivity states and vice versa. This type of policy raises domestic employment and output in bad states of nature relative to what it would be without fiscal policy intervention, which eases liquidity constraints and smoothens out consumption. The optimal state-contingent tax policy implies an empirically realistic variability of labor tax rates, with a standard deviation of around 3–4 percent per year. Finally, the result that state-contingent labor tax policy can be welfare-improving is robust to alternative specifications of the policy rule and variations in the curvature of the penalty function.

The paper contributes to two strands of business cycle literature. The first is the analysis of business cycles in emerging market economies. García-Cicco, Pancrazi, and Uribe (2007) have shown that the small open economy version of the standard neoclassical growth model performs rather poorly when applied to emerging market (Argentine) data. The problem is that the standard model predicts a smooth path of consumption over time, whereas consumption in emerging market economies is highly procyclical and volatile. On the other hand, following the seminal contributions on the interaction of credit constraints and macroeconomic volatility by Kiyotaki and Moore (1997) and Kiyotaki (1998), Kocherlakota (2000) has shown that shocks can potentially be amplified in a small open economy environment with borrowing constraints.

However, models with financial constraints that imply limits on the level of foreign debt have not been particularly successful in matching emerging market data either (for an overview, see Arellano and Mendoza, 2002). The reason is that agents have an incentive to accumulate a buffer stock of assets under uncertainty. Therefore, if borrowing constraints turn binding, agents can simply consume out of their accumulated savings. Rather counterfactually, even very tight borrowing constraints therefore do not have significant effects on macroeconomic outcomes at business cycle frequencies. Valderrama (2002), building on work by Mendoza (2002), instead considers liquidity constraints implying a restriction on the flow of assets. I follow Valderrama's approach in this paper, and I show that the inclusion of liquidity constraints, or current account restrictions, in the standard model mimics Argentine data more successfully than the frictionless version of the model. In particular, the volatility and procyclicality of consumption generated by the model increases the tighter the constraints.

Another issue is that existing research often starts from the assumption that financial constraints are permanently binding (see Meeks, 2003, Cordoba and Ripoll, 2004, Iacoviello, 2005, and Guajardo, 2008). This assumption is arguably implausible. In fact, financial frictions often only have adverse effects on the real side of the economy in bad states of nature. This observation is especially relevant for emerging market economies. I therefore analyze the effects of a financial constraint that is occasionally binding. The non-linearity of the model then imposes a considerable challenge on the numerical solution procedure. Building on work by Kim, Kim, and Kollmann (2005) and den Haan and de Wind (2008), this problem is solved by combining a penalty function approach with standard numerical solution (perturbation) techniques in the quantitative part of the paper. This approach outperforms many alternative (global) solution methods in terms of ease of implementation and computational efficiency.

The second field of related literature is the analysis of optimal tax policy in business cycle models. One of the main results of that literature is that tax rates on labor income should be steady across time (Barro, 1979) and states (Lucas and Stokey, 1983) in otherwise frictionless environments, which is usually referred to as tax smoothing. The reason is that the welfare cost of distortionary taxation is convex in the level of taxes, such that consumers prefer constant tax rates over fluctuating ones (Aiyagari, 1989). For example, if people know that the labor income tax rate will be much higher tomorrow than it is today, then they will work more today and enjoy more leisure tomorrow. A policy of maintaining the tax rate roughly constant would not create similar incentive effects to shift work intertemporally through time, and would thus lead to a higher average level of private consumption. The tax smoothing hypothesis has been supported in the neoclassical growth model for the closed economy by Aiyagari, Marcet, Sargent, and Seppala (2002), and Chen (2003). However, Zhu (1992) and Chari, Christiano, and Kehoe (1994) have shown that, for the class of utility functions commonly used in business cycle analysis, there is no theoretical and quantitative presumption for labor tax smoothing in the neoclassical growth model.

With respect to small open economy models, Fisher and Kingston (2004) have shown in a theoretical study that tax smoothing is optimal if the coefficient of relative risk aversion and the compensated elasticity of labor supply are constant, and if transfers are

untaxed. However, constancy of the labor supply elasticity requires rather restrictive assumptions on preferences. Using quantitative analysis, Kim and Kim (2005) have shown that, for a general class of utility functions, the scope of fiscal stabilization policy using state-contingent taxes is limited due to the buffer stock role of the current account. The motivation for cyclical tax policy in this paper, on the other hand, is the lack of self-insurance by domestic consumers and the associated limits to consumption smoothing. If a government commits to such a policy, it can provide some of the missing insurance to domestic consumers by cutting taxes in bad states of nature (and vice versa). In a world with imperfect capital markets, the stabilization gains from cyclical tax rates thus outweigh the losses from intertemporal tax distortions discussed by Barro (1979).

The remainder of the paper is structured as follows. Section 2 describes the model and derives its deterministic steady state. Section 3 explains the penalty function approach used to solve the model, and discusses the business cycle dynamics generated by the model. Section 4 analyzes the effects of state-contingent labor tax policy, and derives the optimal cyclical labor tax. Section 5 checks the sensitivity of the quantitative results. Section 6 concludes.

## 2 The Model Economy

This section incorporates liquidity constraints on the consumer side in the standard neo-classical growth model of the small open economy described by Mendoza (1991), which has been applied to many quantitative business cycle questions.<sup>1</sup> The model economy features competitive factor markets for labor and capital, non-state-contingent debt, endogenous discounting, and capital adjustment costs. The liquidity constraint considered has been proposed by Valderrama (2002) building on work by Mendoza (2002). It implies a restriction on the flow of assets, *i.e.* the domestic current account deficit. In addition, distortionary labor income taxes are included in the model.

### 2.1 Domestic Agents

Consider a small open economy populated by a continuum of infinitely lived, identical households of mass one. The economy is small in the sense that it takes the path of world interest rates as given. There are no barriers to trade. The objective of a representative domestic household is to maximize expected lifetime utility, given by Uzawa (1968) type preferences:

$$V_0 \equiv E_0 \sum_{t=0}^{\infty} \gamma_t U(c_t, 1 - n_t), \quad (1)$$

where  $c_t$  and  $n_t \in [0, 1]$  denote consumption of a homogeneous good and hours worked, respectively, and  $\gamma_t$  is a time-varying discount factor. The period utility function  $U$  is twice continuously differentiable and strictly concave in both arguments. The discount

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<sup>1</sup>See, for instance, Correia, Neves, and Rebelo, 1994, Neumeyer and Perri, 2005, Uribe and Yue, 2006, Aguiar and Gopinath, 2007, and García-Cicco *et al.*, 2007.

factor satisfies the following conditions (see Schmitt-Grohé and Uribe, 2003):

$$\gamma_0 = 1, \quad \gamma_{t+1} = \beta(\tilde{c}_t, \tilde{n}_t)\gamma_t \quad \forall t \geq 0, \quad \beta_{\tilde{c}}(\cdot) < 0, \quad \beta_{\tilde{n}}(\cdot) > 0,$$

where  $\tilde{c}_t$  and  $\tilde{n}_t$  denote the average per capita levels of consumption and hours worked, which the individual household takes as given. Thus, agents become more impatient the higher the level of average consumption, and vice versa for hours worked. This preference specification is a common (though purely technical) means of ensuring that small open economy models with incomplete asset markets produce well-defined, stationary equilibrium dynamics. Schmitt-Grohé and Uribe (2003) demonstrate that endogenous discounting and alternative stationarity-inducing techniques such as debt-elastic interest rates or portfolio adjustment costs produce virtually identical dynamics at business cycle frequencies. However, endogenous discounting is the most appropriate technique in a model with large, non-linear adjustments due to liquidity constraints (see Arellano and Mendoza, 2002).<sup>2</sup>

The production side of the economy is represented by a large number of identical, perfectly competitive firms. A representative firm produces output  $y_t$  with a constant returns to scale production function  $F$  that takes capital  $k_{t-1}$  and labor services  $n_t$  as inputs,

$$y_t = a_t F(k_{t-1}, n_t), \tag{2}$$

where  $a_t$  is an exogenous (total factor) productivity shock with law of motion

$$\log a_t = \rho \log a_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim \text{NID}(0, \sigma_\varepsilon^2), \quad \rho_a \in [0, 1), \quad \sigma_\varepsilon \geq 0.$$

Competitive price-setting implies that the rental rate of capital  $r_t^k$  and the real wage rate  $w_t$  are equal to the marginal products of capital and labor, respectively:<sup>3</sup>

$$r_t^k = a_t F_k(t), \tag{3}$$

$$w_t = a_t F_n(t). \tag{4}$$

Domestic households earn factor income from supplying labor services and capital to the firms. They pay a proportional tax on their labor income at a rate  $\tau_t^n$ , and they receive lump-sum government transfers  $\tau_t$ . Capital accumulates according to the law of motion

$$k_t = (1 - \delta)k_{t-1} + i_t, \tag{5}$$

where  $k_t$  and  $k_{t-1}$  denote the beginning- and end-of-period stocks of physical capital,  $i_t$  denotes period  $t$  gross investment, and  $\delta \in [0, 1]$  is the depreciation rate. Further-

<sup>2</sup>Kim and Kose (2003) discuss the similarity of models with a constant discount factor and endogenous discounting in terms of their business cycle implications. Schmitt-Grohé and Uribe (2003) show that the specification used above is quantitatively equivalent to one where households internalize the fact that their discount factor depends on their *own* levels of consumption and work effort. The specification without internalization has the (computational) advantage that the model features one less Euler equation and one less Lagrangean multiplier.

<sup>3</sup>Henceforth, period  $t$  objects are denoted by  $F_k(t) \equiv F_k(k_{t-1}, n_t)$ ,  $F_n(t) \equiv F_n(k_{t-1}, n_t)$ , and so on.

more, households face convex costs of adjusting the capital stock as a function  $\Phi$  of net investment  $k_{t+1} - k_t$  as in Mendoza (1991), for simplicity, with  $\Phi(0) = \Phi'(0) = 0$ .<sup>4</sup>

Households can further trade in one-period, risk-free debt at a real interest rate  $r_t^d$ . Free capital mobility together with the small open economy assumption imply that  $r_t^d = r$ , where  $r$  denotes the (constant) world interest rate. The outstanding amount of debt at the beginning of period  $t$  is denoted by  $d_{t-1}$ . This debt is to be repaid during period  $t$  and new debt  $d_t$  is then contracted, which increases current resources. Hence, the period-by-period budget constraint of a representative household is given by

$$c_t + k_t + \Phi(k_t - k_{t-1}) + (1+r)d_{t-1} \leq d_t + (1-\delta)k_{t-1} + (1-\tau_t^n)w_t n_t + r_t^k k_{t-1} + \tau_t. \quad (6)$$

However, international financial markets are imperfect. Following Mendoza (2002) and Valderrama (2002), I introduce a liquidity requirement that allows foreign investors to limit the risk of facing situations in which the current income of domestic households falls short of what is needed to pay for existing debt obligations. In particular, households are required to finance at least a fraction  $\omega \in (0, 1)$  of their current expenditures, capital investment, tax and interest payments out of their current factor income:

$$\omega [c_t + i_t + \Phi(k_t - k_{t-1}) + r d_{t-1} + \tau_t^n w_t n_t - \tau_t] \leq w_t n_t + r_t^k k_{t-1}. \quad (7)$$

Since period utility is strictly concave, the budget constraint (6) will hold with equality in the optimum. That is, applying the capital accumulation equation (5) in the budget constraint,

$$c_t + i_t + \Phi(k_t - k_{t-1}) + r d_{t-1} + \tau_t^n w_t n_t - \tau_t = d_t - d_{t-1} + w_t n_t + r_t^k k_{t-1}.$$

Using this equation in the liquidity requirement (7), we then obtain a restriction on the current account deficit of the form

$$d_t - d_{t-1} \leq \frac{1-\omega}{\omega} (w_t n_t + r_t^k k_{t-1}). \quad (8)$$

Let  $\kappa \equiv (1-\omega)/\omega > 0$ . This restriction says that the current account deficit cannot exceed a multiple  $\kappa$  of current factor income. Notice that equilibrium output  $a_t F(t)$  equals factor income  $a_t [F_n(t)n_t + F_k(t)k_{t-1}]$  under a constant returns to scale production function. The equilibrium current account deficit can therefore not exceed a multiple  $\kappa$  of domestic output.<sup>5</sup>

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<sup>4</sup>Small open economy models typically feature capital adjustment costs in order to avoid excessive volatility of investment caused by the separation of domestic savings and investment through the access to foreign finance. In fact, Mendoza (1991) shows that models with free capital accumulation exaggerate the volatility of investment and underestimate its correlation with savings. These two anomalies can be avoided by introducing moderate capital adjustment costs.

<sup>5</sup>The caveats discussed by Mendoza (2002), Arellano and Mendoza (2002), and Valderrama (2002) do of course apply. In particular, it should be noted that the liquidity requirement (7) is directly imposed and thus not derived from an optimal contract. However, a current account restriction such as (8) may arise in a world of imperfect information where agents do not know the true state of an economy or its indebtedness, and thus have an incentive to monitor the rate of buildup of foreign debt (Valderrama, 2002). Other authors have emphasized the importance of large current account deficits as sources of financial crises (see Milesi-Ferretti and Razin, 1996, and Edwards, 2001). Finally, there are strong notions that liquidity constraints matter for business cycle analysis (see Kiyotaki and Moore, 2008).

The representative household's optimization problem is then to solve

$$\begin{aligned} & \max_{\{c_t, n_t, d_t, k_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \gamma_t U(c_t, 1 - n_t) \\ \text{s.t. } & c_t + k_t + \Phi(k_t - k_{t-1}) + (1 + r)d_{t-1} \\ & = d_t + (1 - \delta)k_{t-1} + (1 - \tau_t^n)w_t n_t + r_t^k k_{t-1} + \tau_t, \\ & d_t - d_{t-1} \leq \kappa(w_t n_t + r_t^k k_{t-1}), \quad k_{-1}, d_{-1} \text{ given.} \end{aligned}$$

The corresponding first-order conditions are given by

$$c_t : \quad U_c(t) = \lambda_t, \quad (9)$$

$$n_t : \quad -U_n(t) = \lambda_t(1 - \tau_t^n)w_t + \mu_t \kappa w_t, \quad (10)$$

$$d_t : \quad \lambda_t - \mu_t = \beta(\tilde{c}_t, \tilde{n}_t) E_t[(1 + r)\lambda_{t+1} - \mu_{t+1}], \quad (11)$$

$$k_t : \quad \lambda_t[1 + \Phi'(t)] = \beta(\tilde{c}_t, \tilde{n}_t) E_t \left\{ \lambda_{t+1}[1 - \delta + r_{t+1}^k + \Phi'(t + 1)] + \mu_{t+1} \kappa r_{t+1}^k \right\}, \quad (12)$$

where  $\lambda_t$  and  $\mu_t$  denote the Lagrangean multipliers on the budget constraint and the current account constraint, respectively. The complementary slackness condition associated with the latter is

$$\mu_t[\kappa(w_t n_t + r_t^k k_{t-1}) - (d_t - d_{t-1})] = 0, \quad \mu_t \geq 0. \quad (13)$$

Furthermore, we require a no-Ponzi-game condition on debt,  $\lim_{t \rightarrow \infty} E_0 d_t / (1 + r)^t = 0$ , and a transversality condition on capital,  $\lim_{t \rightarrow \infty} E_0 \gamma_t \lambda_t k_t = 0$ .

Notice that the presence of liquidity constraints leads to both intratemporal and intertemporal distortions of the households' optimality conditions. First, condition (11) shows that a household that optimally allocates a marginal unit of wealth has an incentive to save more if (8) is binding today ( $\mu_t > 0$ ), since the effective interest rate on savings increases. That is, households would tend to accumulate a buffer stock of savings. However, there is an opposite effect if the constraint is expected to be binding in the future ( $E_t \mu_{t+1} > 0$ ). The benefit of savings then decreases, since the current account restriction limits the extent to which accumulated assets can be liquidated. Second, condition (10) says that the marginal disutility of working time has to equal the marginal increase in wealth through working plus a term  $\mu_t \kappa w_t$  that measures the relaxation of (8) through higher labor income. Thus, households would want to work more in order to increase their liquidity, which in turn reduces the tightness of the constraint. Third, condition (11) shows that households would also want to accumulate more capital than in the unconstrained case. Here, the term  $\beta(\tilde{c}_t, \tilde{n}_t) E_t \mu_{t+1} \kappa r_{t+1}^k$  measures the expected relaxation of (8) through higher capital accumulation.

## 2.2 Government

Since we are interested in the stabilizing effects and the associated welfare impact of alternative tax policies, exogenous government goods purchases and government debt are irrelevant for the analysis. The specification of the government sector is therefore



highly stylized. Government spending is fixed at zero, and the government does not issue any debt. The government has a single tax instrument available, a labor income tax. Following Kim and Kim (2005), I assume that it steers this instrument according to the following feedback rule:

$$\tau_t^n = \bar{\tau}^n + \tau^a(a_t - \bar{a}), \quad (14)$$

where  $\bar{\tau}^n$  denotes the average (steady state) labor income tax rate and  $\bar{a}$  denotes the unconditional mean of the productivity shock.<sup>6</sup> The sign of the feedback coefficient  $\tau^a$  determines whether labor tax rates react procyclically (if positive) or countercyclically (if negative) to the state of productivity.

This type of policy rule is based on the implicit assumption that the government can directly react to changes in productivity. That assumption is problematic, since productivity is usually not directly observed, and if it is, it may only be observed with a lag. The alternative of letting taxes react to observable data such as output would imply that the average tax rate changes across alternative policies, since in general stochastic and deterministic means of endogenous variables will differ in a non-linear model. The effects of changes in average taxes are however well-documented, see for instance McGrattan (1994). Letting taxes react to the exogenous shock is thus more appropriate in our set-up, since it allows us to focus on the stabilizing effects of alternative tax policies under identical average distortionary taxes. In order to address the fact that productivity may only be observed with a lag, I will compare the results with a specification where  $a_{t-1}$  replaces  $a_t$  in equation (14) in Section 5.

The government furthermore balances its budget by rebating all tax revenue to the households via lump-sum transfers  $\tau_t$ . This assumption ensures that there are no effects from wasteful government spending on welfare.<sup>7</sup> Hence, the government budget constraint takes the simple form

$$\tau_t = \tau_t^n w_t n_t. \quad (15)$$

The objective of the government is to pick the optimal feedback coefficient  $\tau^{a*}$  which maximizes social welfare. I assume that the government commits to a particular policy at the beginning of time. Households then form their decisions according to their welfare-maximizing plan.

### 2.3 Competitive Equilibrium

In equilibrium, individual and average per capita variables are identical, *i.e.*  $c_t = \tilde{c}_t$  and  $n_t = \tilde{n}_t$ . Using the government budget constraint (15) and the capital accumulation equation (5) in the representative household's budget constraint (6), we obtain the following aggregate resource constraint:

$$y_t = c_t + i_t + \Phi(k_t - k_{t-1}) + (1 + r)d_{t-1} - d_t. \quad (16)$$

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<sup>6</sup>Throughout,  $\bar{x}$  denotes the value of an endogenous variable  $x_t$  in a deterministic steady state, where  $x_{t+1} = x_t$  for all  $t$ .

<sup>7</sup>Alternatively, one could assume that there is a welfare-augmenting public good which enters into the representative household's utility function in a separable way. Government goods purchases would then have no direct impact on household decisions.

Then, a *competitive equilibrium* is a set of sequences  $\{c_t, n_t, k_t, d_t, y_t, r_t^k, w_t, \tau_t, \lambda_t, \mu_t\}_{t=0}^{\infty}$  satisfying the households' optimality conditions (9)–(11), the firms' production and optimality conditions (2)–(4), the complementary slackness condition (13), the boundedness conditions on debt and capital, the government budget constraint (15), and the resource constraint (16), given a policy  $\{\tau_t^n\}_{t=0}^{\infty}$ , a sequence of shocks  $\{a_t\}_{t=0}^{\infty}$ , and initial values  $a_{-1}$ ,  $k_{-1}$  and  $d_{-1}$ .

## 2.4 Functional Forms and Steady State

I parameterize preferences, production technology and adjustment costs as follows:

$$\begin{aligned} U(c_t, 1 - n_t) &= \frac{(c_t^\theta (1 - n_t)^{1-\theta})^{1-\sigma}}{1 - \sigma}, \quad \theta > 0, \quad \sigma > 1, \\ \beta(\tilde{c}_t, \tilde{n}_t) &= \left(1 + c_t^\theta (1 - n_t)^{1-\theta}\right)^\psi, \quad \psi < 0, \\ F(k_{t-1}, n_t) &= k_{t-1}^\alpha n_t^{1-\alpha}, \quad \alpha \in (0, 1), \\ \Phi(k_t - k_{t-1}) &= \frac{\phi}{2}(k_t - k_{t-1})^2, \quad \phi > 0. \end{aligned}$$

The functional forms of  $\beta$ ,  $F$  and  $\Phi$  follow directly from the standard set-up in Mendoza (1991) and Schmitt-Grohé and Uribe (2003). Notice however that the period utility function  $U$  is of the Cobb-Douglas form. The general class of utilities typically used in closed-economy RBC models is thus adopted, and not the type of preferences due to Greenwood, Hercowitz, and Huffman [GHH] (1988). GHH preferences have helped small open economy models to match real-world data by making the marginal rate of substitution between consumption and labor independent of consumption, which eliminates wealth effects on labor supply. The problem is that access to international financial markets under fixed interest rates presents households with additional consumption smoothing opportunities, which tends to make the volatility and procyclicality of consumption too small in models with Cobb-Douglas preferences.

In small open economy models, GHH utility thus usually mimics business cycles better than the Cobb-Douglas specification, albeit at the cost of a counterfactual perfect correlation between hours worked and output.<sup>8</sup> The reasons for the use of the latter type of preferences in our set-up are then threefold. First, the Cobb-Douglas specification has been an important benchmark in the business cycle literature since Kydland and Prescott (1982) and Prescott (1986). Second, a model with financial market imperfections such as ours should strive to explain the volatility and procyclicality of consumption independently of the form of preferences and technology. Third, it seems important to exclude any *a priori* impact of non-standard assumptions on preferences on our analysis of optimal tax policy.<sup>9</sup>

<sup>8</sup>See Correia *et al.* (1994) for an application to a developed small open economy, and Neumeyer and Perri (2005) for an application to emerging market data.

<sup>9</sup>See Zhu (1992) and Chari *et al.* (1994) for applications of Cobb-Douglas preferences in optimal policy problems.

In a deterministic steady state, the current account restriction (8) implies that  $0 \leq \kappa \bar{y}$ . Therefore, (8) is not binding in the steady state, since  $\bar{y} > 0$  and  $\kappa = (1 - \omega)/\omega > 0$  for  $\omega \in (0, 1)$ . Throughout this paper, I thus fix an average debt-to-GDP ratio  $\bar{d}_y \equiv \bar{d}/\bar{y}$  in order to uniquely pin down the deterministic steady state. The free parameter  $\psi$ , which measures the sensitivity of the endogenous discount factor with respect to changes in consumption and hours worked, is then adjusted to match the choice of  $\bar{d}_y$ .

The productivity shock is equal to its unconditional mean in a deterministic steady state, *i.e.*  $\bar{a} = 1$ . With the functional forms given above, the equilibrium conditions can then be written as

$$\frac{1 - \theta}{\theta} = \frac{1 - \bar{n}}{\bar{c}}(1 - \bar{\tau}^n)\bar{w}, \quad (17)$$

$$1 = \left(1 + \bar{c}^\theta(1 - \bar{n})^{1-\theta}\right)^\psi (1 + r), \quad (18)$$

$$1 = \left(1 + \bar{c}^\theta(1 - \bar{n})^{1-\theta}\right)^\psi [1 - \delta + \bar{r}^k], \quad (19)$$

$$\bar{r}^k = \alpha(\bar{k}/\bar{n})^{\alpha-1}, \quad (20)$$

$$\bar{w} = (1 - \alpha)(\bar{k}/\bar{n})^\alpha, \quad (21)$$

$$\bar{y} = \bar{n}(\bar{k}/\bar{n})^\alpha, \quad (22)$$

$$\bar{y} = \bar{c} + \delta\bar{k} + r\bar{d}, \quad (23)$$

$$\bar{\tau} = \bar{\tau}^n \bar{w} \bar{n}. \quad (24)$$

It follows from (18) that the steady state discount factor satisfies  $\beta(\bar{c}, \bar{n})(1 + r) = 1$ . We then obtain the steady state rental rate from (19) as  $\bar{r}^k = r + \delta$ , such that the steady state capital-labor ratio follows by (20) as

$$\frac{\bar{k}}{\bar{n}} = \left(\frac{\alpha}{r + \delta}\right)^{\frac{1}{1-\alpha}}.$$

The steady state wage rate then follows directly from (21).

Furthermore, the resource constraint (23) and (22) imply that  $\bar{c}/\bar{y} = 1 - \delta(\bar{k}/\bar{n})^{1-\alpha} - r\bar{d}_y$ . Now we can rewrite (17) using (21) and (22) in order to pin down steady state hours worked:

$$\bar{n} = \left[1 + \frac{(1 - \theta)}{\theta(1 - \alpha)(1 - \bar{\tau}^n)} \frac{\bar{c}}{\bar{y}}\right]^{-1}.$$

Steady state capital then follows from  $\bar{k} = \bar{n}(\bar{k}/\bar{n})$ , and steady state consumption follows directly from (23). Steady state lump-sum transfers  $\bar{\tau}$  follow directly from (24).

Finally,  $\psi$  can be calibrated to match our choice of  $\bar{d}_y$ . To see this, notice that for a given value of  $\bar{k}/\bar{n}$ , both  $\bar{n}$  and  $\bar{k}$ , and therefore also  $\bar{y}$  are independent of  $\psi$ . Then  $\bar{d}$  is independent of  $\psi$ , since it follows as  $\bar{d} = \bar{y}\bar{d}_y$ . Given the values of  $\bar{y}$ ,  $\bar{k}$  and  $\bar{d}$ , steady state consumption follows directly from (23), independently of  $\psi$ . The value of  $\psi$  that is consistent with the choice of  $\bar{d}_y$  can then be calculated by making (19) hold, that is

$$\psi = \frac{-\log(1 + r)}{\log\left(1 + \bar{c}^\theta(1 - \bar{n})^{1-\theta}\right)}.$$

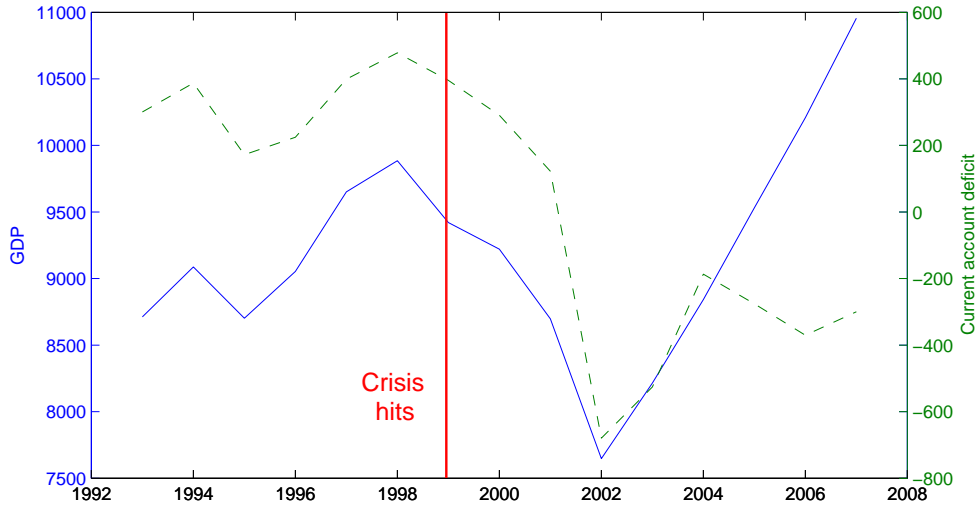


Figure 1: GDP and current account deficit in Argentina, 1993–2007. *Notes.* Solid line (left axis): GDP per capita in constant 1993 Argentine pesos; dashed line (right axis): current account deficit per capita in constant 1993 Argentine pesos.

Notice that the steady state values are independent of the borrowing limit  $\kappa$  and the feedback coefficient  $\tau^a$ . That is, we can fix the deterministic steady state of the model when comparing alternative tax policies, while varying the tightness of the current account constraint.

### 3 Liquidity Constraints and Business Cycles

This section documents the business cycle dynamics generated by a calibrated version of the model economy described in the previous section. The model is parameterized so as to make it roughly consistent with the empirical regularities of business cycles in Argentina for the period 1993–2007. Argentina is viewed as a typical emerging market economy where restrictions on current account borrowing were an important feature of past economic experience. The period considered is characterized by a severe financial and economic crisis in 1999–2002, during which the country increasingly lost the confidence of foreign investors. When Argentina defaulted on its foreign debt in 2002, capital inflows had ceased and the country had effectively lost access to international financial markets (see Feldstein, 2002).

At the risk of oversimplification, Figure 1 provides some evidence on the issue. The figure shows real GDP per capita and the per capita current account deficit in Argentina during 1993–2007. Notice that there was a strong co-movement between the two aggregates during that period. When the crisis hit in 1999, GDP per capita declined dramatically and the current account deficit rapidly turned into a surplus. The observation of a procyclical current account deficit contradicts the predictions of standard open

economy business cycle models, in which the current account deficit acts as an absorber of shocks, thus moving *countercyclically*.

Our model, however, can provide some guidance on appropriate policy actions in a situation in which the current account deficit is procyclical. Given the observations on the Argentine experience, the theoretical framework is applied in a scenario where (i) the economy is hit by an adverse initial shock, proxied by a productivity shock, which (ii) puts the economy in a situation in which liquidity constraints and restrictions on current account borrowing are relevant, proxied by a relatively small value of the borrowing limit  $\kappa$ . Here, one may think of a loss in investor confidence which triggers the current account constraint.

### 3.1 Penalty Function Approach

Due to the non-linearity (non-differentiability) caused by the current account constraint, our model does not easily lend itself to standard numerical solution techniques. Ideally, one should apply a global solution method to properly account for that non-linearity. One such method that is often used to solve models with occasionally binding inequality constraints is value function iteration.<sup>10</sup> Alternatively, one might apply a projection algorithm that works on the Lagrangean multiplier  $\mu_t$  (see Christiano and Fisher, 2000). However, due to computational limitations both methods are rather cumbersome to apply in our current set-up.

In order to address these issues and to simplify the original non-linear model, I “soften” the current account constraint using a penalty function formulation.<sup>11</sup> The idea is to replace the inequality constraint (8) by a differentiable penalty function that enters into the objective function of the representative household. This leads to a modified problem where any current account deficit is feasible, but it is costly to exceed the limit given by (8). This modification makes it possible to apply standard local approximation (perturbation) techniques, which on the basis of computational feasibility and ease of implementation clearly dominate many alternative methods.<sup>12</sup>

I apply the following penalty function specification:

$$P(d_t, n_t, d_{t-1}, k_{t-1}) = \frac{\eta_1}{\eta_0} \exp[-\eta_0(\kappa(w_t n_t + r_t^k k_{t-1}) - (d_t - d_{t-1}))] \\ - \eta_2(d_t - d_{t-1}) + \eta_3 n_t + \eta_4 k_{t-1} - \eta_5,$$

where  $\eta_0, \eta_1 > 0$  and  $\eta_i \geq 0$  for  $i = 2, \dots, 5$ . This specification is a modified version of the penalty function analyzed by den Haan and de Wind (2008), who approximate a non-state-contingent borrowing constraint. Here, the arguments  $d_t, n_t, d_{t-1}$  and  $k_{t-1}$  are included to emphasize the fact that the penalty depends on the household’s choices and the state of the economy. For a given limit  $\kappa$ , the parameter  $\eta_0$  controls the curvature

<sup>10</sup>See, for example, Mendoza (1991), Mendoza (2002), Arellano and Mendoza (2002), or Valderrama (2002).

<sup>11</sup>See Judd (1998), Kim *et al.*, 2005, and den Haan and de Wind (2008).

<sup>12</sup>The Matlab package Dynare (version 4.0.2) is used to solve the model. The package is freely available from [www.ceprenmap.cnrs.fr/dynare](http://www.ceprenmap.cnrs.fr/dynare).

of the penalty function. If we let  $\eta_0 \rightarrow \infty$ , the household receives an infinite penalty if the change in its indebtedness exceeds the limit  $\kappa(w_t n_t + r_t^k k_{t-1})$ . The penalty function formulation is then equivalent to the original problem, since the optimal solution will never feature an allocation where (8) is violated.<sup>13</sup> The parameter  $\eta_1$  controls the shape of the penalty function, a smaller  $\eta_1$  implying a flatter penalty function. As suggested by den Haan and de Wind (2008), the value of  $\eta_1$  will be adjusted to match a moment in the data. Finally, for finite  $\eta_0$  and relatively small  $\kappa$  the penalty function and its derivatives will be different from zero at the deterministic steady state. This is inconsistent with the fact that the deterministic steady state is independent of the value of  $\kappa$ . Therefore, the remaining parameters  $\eta_i$ ,  $i = 2, \dots, 5$ , are introduced in order to ensure that these terms drop out at the steady state.

Adopting the penalty function formulation given above, the modified version of the representative household's problem is as follows:

$$\begin{aligned} & \max_{\{c_t, n_t, d_t, k_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \gamma_t [U(c_t, 1 - n_t) - P(d_t, n_t, d_{t-1}, k_{t-1})] \\ \text{s.t. } & c_t + k_t + \Phi(k_t - k_{t-1}) + (1 + r)d_{t-1} \\ & = d_t + (1 - \delta)k_{t-1} + (1 - \tau_t^n)w_t n_t + r_t^k k_{t-1} + \tau_t, \\ & k_{-1}, d_{-1} \text{ given.} \end{aligned}$$

We then have the following first-order conditions:<sup>14</sup>

$$\begin{aligned} c_t : & U_c(t) = \lambda_t, \\ n_t : & -U_n(t) = \lambda_t(1 - \tau_t^n)w_t + \eta_1 \exp[-\eta_0(\kappa(w_t n_t + r_t^k k_{t-1}) - (d_t - d_{t-1}))]\kappa w_t - \eta_3, \\ d_t : & \beta(\tilde{c}_t, \tilde{n}_t)E_t \left\{ (1 + r)\lambda_{t+1} - \eta_1 \exp[-\eta_0(\kappa(w_{t+1}n_{t+1} + r_{t+1}^k k_t) - (d_{t+1} - d_t))] + \eta_2 \right\} \\ & = \lambda_t - \eta_1 \exp[-\eta_0(\kappa(w_t n_t + r_t^k k_{t-1}) - (d_t - d_{t-1}))] + \eta_2, \\ k_t : & \lambda_t[1 + \Phi'(t)] = \beta(\tilde{c}_t, \tilde{n}_t)E_t \left\{ \lambda_{t+1}[1 - \delta + r_{t+1}^k + \Phi'(t + 1)] \right. \\ & \left. + \eta_1 \exp[-\eta_0(\kappa(w_{t+1}n_{t+1} + r_{t+1}^k k_t) - (d_{t+1} - d_t))]\kappa r_{t+1}^k - \eta_4 \right\}. \end{aligned}$$

Compare these conditions with the original system (9)–(11). In particular, notice that the derivatives of the penalty function replace the shadow prices of the current account constraint in (9)–(11). In fact, the purpose of the penalty terms is similar to that of the shadow prices, namely to discourage agents from violating the constraint.

<sup>13</sup>Den Haan and de Wind (2008) discuss conditions under which a model with penalty function can be solved with low-order perturbation up to a satisfactory degree of accuracy. In particular, the curvature of the penalty function should not be too large such that low-order perturbation can handle the non-linearity of that function. On the other hand, the approximation of the model with inequality constraint is satisfactory even with relatively low curvature.

<sup>14</sup>These conditions substitute (9)–(11) as equilibrium conditions. We further require the same boundedness conditions as previously, but the complementary slackness condition for (8) is now obviously redundant.

### 3.2 Data and Calibration

The model is calibrated to match Argentine data on real GDP, personal consumption, hours worked, gross fixed investment, exports and imports of goods and services, and the current account. The data correspond to annual observations for the period 1993–2007, except for hours worked for which a consistent series was only available for the period 1996–2005.<sup>15</sup> All variables are expressed in per capita terms of the population older than 10 years, and detrended using the Hodrick-Prescott filter with a smoothing parameter of 6.25 as suggested by Ravn and Uhlig (2002). The data are measured in millions of Argentine pesos at constant 1993 prices, except for hours worked and the current account. The raw data on the current account are in millions of US dollars at current prices, and converted into Argentine pesos at 1993 prices using the nominal peso-dollar exchange and the GDP deflator with base year 1993. Hours are measured in average weekly hours worked of persons aged 10 years and over in 28 urban agglomerations.<sup>16</sup>

The baseline calibration of the deep structural parameters  $\sigma$ ,  $\theta$ ,  $\alpha$ ,  $r$ ,  $\delta$ ,  $\phi$ ,  $\sigma_\varepsilon$ ,  $\rho$ ,  $\bar{d}_y$ , and  $\omega$  is reported in Table 1. Some of the parameters are set to standard values used in related business cycle studies. The coefficient of relative risk aversion  $\sigma$  is set to 2, a value that is commonly used in the RBC literature. The consumption share parameter  $\theta$  is set to match a steady state value of hours worked of 0.2, which implies that households allocate on average 20 percent of their available time to labor market activities. This dogmatic choice of  $\theta$  is roughly consistent with the average time devoted to market work per person in the data, which equals 25 percent of available time. There is no reliable data on factor income shares for Argentina (see García-Cicco *et al.*, 2007). The share of capital in output  $\alpha$  is therefore set to the conventional value 0.32. The annual world interest rate  $r$  is set to 8.5 percent. García-Cicco *et al.* (2007) argue that this choice is empirically plausible for an emerging market economy such as Argentina. An annual depreciation rate  $\delta$  of 12.5 percent matches the observed average investment-to-output ratio of 19 percent. The adjustment cost parameter  $\phi$  is then chosen to mimic the variability of investment observed in the data. The productivity parameters  $\sigma_\varepsilon$  and  $\rho$  are adjusted to mimic the observed variability and persistence of output. The average debt-to-GDP ratio  $\bar{d}_y$  is chosen to match an observed average trade-balance-to-GDP ratio of 0.5 percent, *i.e.*  $r\bar{d}/\bar{y} = 0.02$ .<sup>17</sup>

The parameter  $\omega$  governing the liquidity requirement is set to a relatively large value of 0.95 for the baseline case, with an implied borrowing limit  $\kappa = 0.05$ . Hence, the baseline case implies a relatively tight restriction on the current account deficit. Still, this is an appropriate choice for our data set. The average Argentine current account

<sup>15</sup>Considering annual data is appropriate in our set-up since tax rates do not fluctuate much at quarterly frequency (see Kim and Kim, 2005). Moreover, labor and population statistics are only available at annual frequency for Argentina.

<sup>16</sup>The source of the data on GDP, consumption, investment, exports, imports, the current account and the GDP deflator is the Instituto Nacional de Estadística de la Republica Argentina. The population data and the data on hours worked are obtained from the International Labour Organization’s LABORSTA database. The source of the exchange rate data is the Banco Central de la Republica Argentina.

<sup>17</sup>The trade balance is defined as the difference between output and domestic absorption,  $tb_t \equiv y_t - c_t - i_t - \Phi(k_t - k_{t-1}) = (1 + r)d_{t-1} - d_t$ , or the difference between exports and imports.

Table 1: Baseline calibration of deep structural parameters.

Parameter	Definition	Value	Target
$\sigma$	Coefficient of relative risk aversion	2	RBC convention
$\theta$	Consumption share parameter	0.26	Steady state hours
$\alpha$	Share of capital in output	0.32	RBC convention
$r$	World real interest rate	0.085	Emerging market rates
$\delta$	Depreciation rate	0.125	Investment-to-GDP ratio
$\phi$	Adjustment cost parameter	0.42	Volatility of investment
$\sigma_\varepsilon$	Std. dev. of productivity innovations	0.021	Volatility of output
$\rho$	Persistence of productivity shocks	0.18	Persistence of output
$\bar{d}_y$	Average debt-to-GDP ratio	0.059	Trade balance-to-GDP ratio
$\omega$	Liquidity requirement	0.95	Max. current account deficit

deficit during 1993–2007 was 0.2 percent of GDP, and the maximum of 4.8 percent was reached right before the crisis in 1999. At this point, the nervousness of investors reached a critical point and capital inflows started to cease (see Feldstein, 2002). A current account borrowing limit of 5 percent of GDP thus seems to be a plausible starting point. In a counterfactual exercise, the limit is then set to two more values: (i)  $\kappa = 20\%$ , a rather mild restriction, and (ii)  $\kappa \rightarrow \infty$  for the case where  $\omega \rightarrow 0$  and liquidity constraints are irrelevant.<sup>18</sup> Notice that all of these values are consistent with the current account constraint not being binding in the deterministic steady state.

Regarding the parameters of the penalty function, the curvature parameter  $\eta_0$  is set to 50. This value falls within the range where the trade-off between the approximation of inequality constraints and the accuracy of low-order (second-order) perturbation is most favorable (see den Haan and de Wind, 2008). Section 5 checks the sensitivity of the results to alternative choices of  $\eta_0$ . It turned out not to be possible to match the observed standard deviation of the current account-to-GDP ratio of 2.2 percent per year for  $\kappa = 0.05$ . The shape parameter  $\eta_1$  is therefore calibrated in order to match the observed volatility of the moment most closely related to the variability of the current account, the standard deviation of the trade balance-to-GDP ratio. This results in the value  $\eta_1 = 0.51$ . For the various values of  $\kappa$ , the parameters  $\eta_i$ ,  $i = 2, \dots, 5$ , are calibrated to ensure that the penalty function and its derivatives are equal to zero at the deterministic steady state. As argued above, this modification is consistent with the fact that the steady state is independent of the value of  $\kappa$ .

With respect to the policy parameters, I proceed as follows. Since estimates of tax rates consistent with those faced by a representative agent in a general equilibrium framework are not available for Argentina, I take the actual income tax faced by the average Argentine resident as a benchmark. Average GDP per capita was approximately 10,700 Argentine pesos in 2007. This would make the average Argentine resident fall into the second (out of seven) tax class with an income tax of 14 percent according to information obtained from the Federation of International Trade Associations; thus,

<sup>18</sup>In practice,  $\kappa$  is set to a value of  $10^7$ .



$\bar{\tau}^n = 0.14$ . Notice that this value is somewhat smaller than estimates of mean labor tax rates in industrialized countries during the period 1965–1988, which lie between 20 and 43 percent, as documented by Mendoza, Razin, and Tesar (1994). The tax feedback coefficient will be varied on the interval  $\tau^a \in [-1, 1]$ . This yields a standard deviation of the labor income tax rate between 5 and 10 percent, which is consistent with the observed volatility of actual tax rates in industrialized countries of approximately 5 percent per year, as reported by Kim and Kim (2005).

Table 2: Observed and implied business cycle statistics.

	Data	$\kappa \rightarrow \infty$	$\kappa = 20\%$	$\kappa = 5\%$
<i>Standard deviations<sup>a</sup></i>				
Output	3.8	4.5	4.1	3.7
Consumption	4.4	0.9	1.2	1.6
Hours worked	1.5	3.4	2.8	2.2
Investment	10.5	4.1	8.8	10.5
Current account / GDP	2.2	3.3	1.7	0.6
Trade balance / GDP	1.5	3.8	2.5	1.5
<i>Relative standard deviations<sup>b</sup></i>				
Consumption	1.16	0.20	0.30	0.42
Hours worked	0.40	0.76	0.69	0.61
Investment	2.78	0.91	2.16	2.86
<i>Autocorrelations<sup>c</sup></i>				
Output	0.40	0.35	0.43	0.40
Consumption	0.39	0.71	0.67	0.68
Hours worked	0.38	0.47	0.57	0.50
Investment	0.26	0.38	0.06	0.09
Current account / GDP	0.14	0.38	0.68	0.79
Trade balance / GDP	0.18	0.51	0.84	0.96
<i>Correlations with output</i>				
Consumption	0.99	0.32	0.49	0.69
Hours worked	0.80	0.98	0.95	0.91
Investment	0.99	0.59	0.84	0.90
Current account / GDP	-0.64	0.92	0.83	0.76
Trade balance / GDP	-0.70	0.99	0.88	0.65

<sup>a</sup> Standard deviations are measured in percent per year, and computed as coefficients of variation for output, consumption, hours worked, and investment.

<sup>b</sup> Relative standard deviations are standard deviations divided by the standard deviation of output.

<sup>c</sup> Autocorrelations are computed as first-order autocorrelations.

### 3.3 Business Cycle Dynamics

In order to obtain an impression of the empirical regularities of Argentine business cycles, the first column in Table 2 reports standard deviations and correlations in the data. A striking aspect of Argentine business cycles is the high volatility and procyclicality of consumption. In fact, consumption is more volatile than output. Another regularity is that the current account-to-GDP ratio is negatively correlated with output, such that the current account deficit is procyclical, and similarly for the trade balance. Finally, Argentine business cycles are characterized by a relatively small variability of hours worked relative to output, whereas the volatility of investment is about three times higher than that of output.

Let us compare these business cycle facts with the statistics generated by the model. Suppose for now, perhaps counterfactually, that the government holds labor tax rates constant over time. Columns 2–4 of Table 2 reports (relative) standard deviations and correlations under this type of policy. Given that we targeted the standard deviation and autocorrelation of output, as well as the standard deviations of investment and the trade balance-to-GDP ratio, the model successfully matches these moments for the baseline case, *i.e.* for  $\kappa = 5\%$ . The model also closely mimics some of the correlations with output. However, the model underpredicts the volatility of consumption whereas it overpredicts the variability of hours worked. It also fails in predicting the strong countercyclicality of the current account and the trade balance observed in the data. In general, these results confirm the findings of García-Cicco *et al.* (2007) on the poor performance of the standard small open economy RBC model in matching emerging market data.

However, it is also obvious that the inclusion of liquidity constraints improves the quantitative performance of the model. Most importantly, we can observe that the current account restriction substantially amplifies the fluctuations of consumption, the more the tighter the constraint. If the current account restriction is 5 percent of GDP, the volatility of consumption is almost double as high as in the frictionless case where  $\kappa \rightarrow \infty$ . Furthermore, the procyclicality of consumption increases, and the current account and the trade balance become somewhat more countercyclical. A similar observation can be made for investment. The reason is, of course, the fact that a tighter constraint limits the consumption smoothing possibilities of domestic consumers. Fluctuations of the current account as a stabilizer of shocks are restricted since the maximum current account deficit is directly linked to the level of GDP. The variability of the current-account-to-GDP ratio therefore declines with the tightness of the constraint, and similarly for the trade balance-to-GDP ratio. Furthermore, the volatility of hours worked also moves in the right direction. The model with tight liquidity constraints therefore matches the relative standard deviations of consumption, investment, and hours worked better than the model with lax constraints.

Figure 2 provides some more intuition on these results. The figure shows the responses of the major macroeconomic aggregates to a negative one-standard deviation shock to productivity, for  $\kappa = 5\%$ ,  $\kappa = 20\%$ , and  $\kappa \rightarrow \infty$ . Observe that the model predicts a procyclical response of the current account-to-GDP ratio and the trade balance-

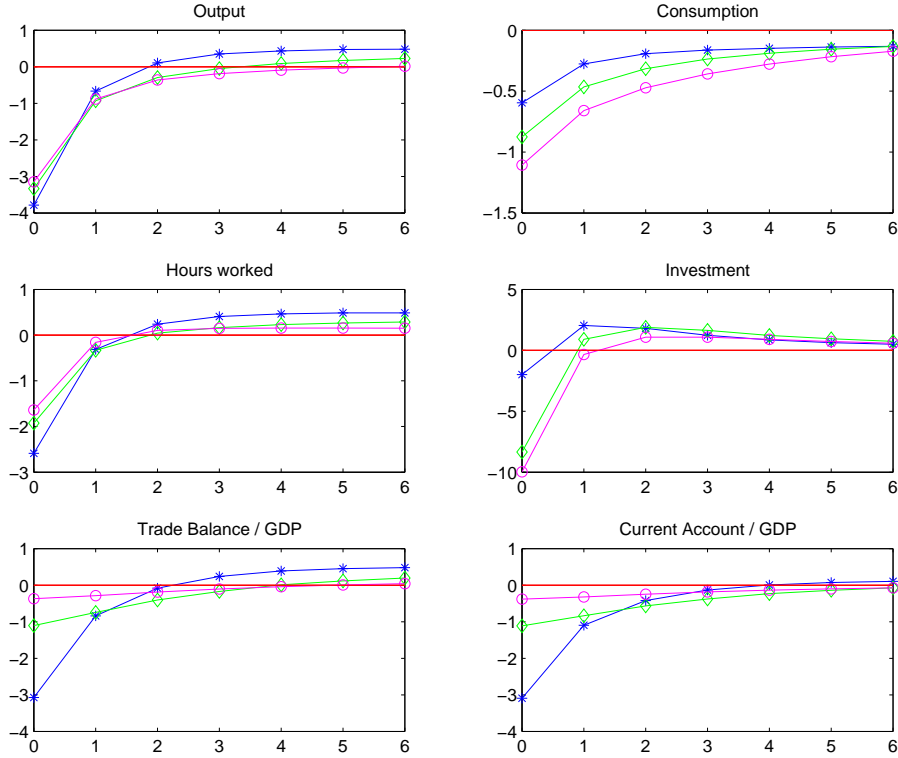


Figure 2: Impulse responses to negative one-standard deviation productivity shock under constant-tax policy. *Notes.* Vertical axes: percentage deviations from deterministic steady state; horizontal axes: years after shock. Stars:  $\kappa \rightarrow \infty$ ; diamonds:  $\kappa = 20\%$ ; circles:  $\kappa = 5\%$ .

to-GDP ratio. Households absorb the adverse productivity shock by borrowing abroad. The response of the current account and the trade balance is however less procyclical under the tight borrowing limit, whereas the procyclicality of consumption increases. On the other hand, the (impact) responses of hours, investment and output are dampened under the tight current account constraint. The explanation for these results is as follows. Due to the current account restriction, the negative productivity shock cannot be absorbed by running a current account deficit over the limit. In order to increase their liquidity, domestic households thus increase working time and, initially, investment. This leads to an increase in domestic output and counteracts the negative impact on consumption, but not enough to prevent consumption from declining.

## 4 Labor Tax Policy

The results of the previous section indicate that the presence of liquidity constraints in a small open economy environment severely limits the self-insurance possibilities of domestic consumers, leading to excessively volatile and procyclical consumption spend-

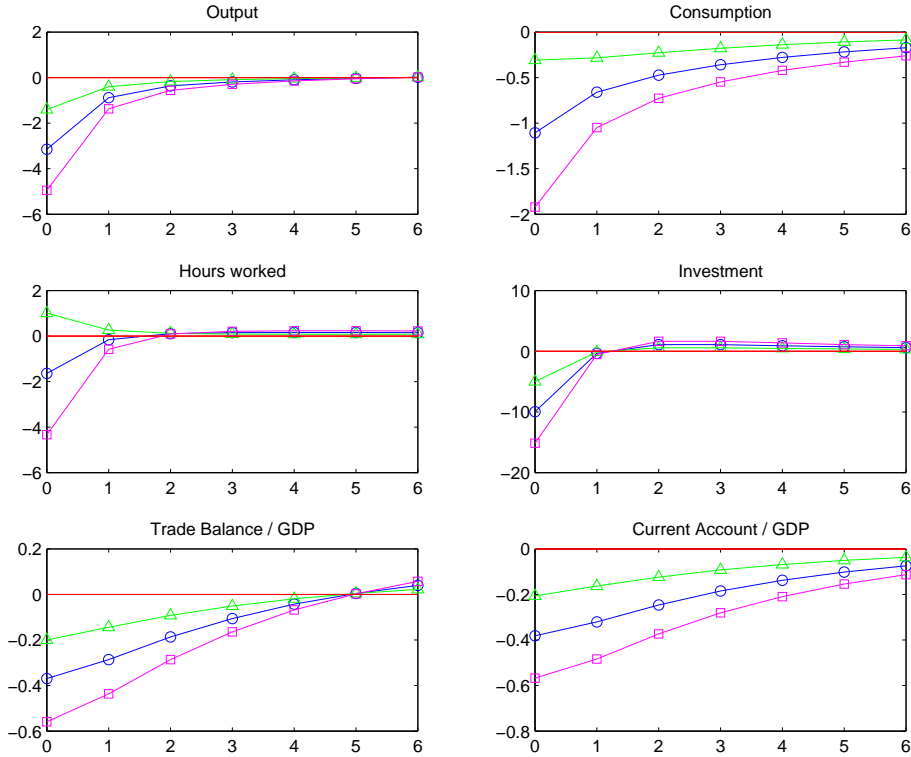


Figure 3: Impulse responses to negative one-standard deviation productivity shock under state-contingent labor tax, for  $\kappa = 5\%$ . *Notes.* Vertical axes: percentage deviations from deterministic steady state; horizontal axes: years after shock. Circles: constant taxes; triangles:  $\tau^a = 1$ ; squares:  $\tau^a = -1$ .

ing. The lack of self-insurance possibilities may then provide a rationale for fiscal policy intervention. This section therefore considers the impact of active, state-contingent tax policy. In particular, I investigate whether a cyclical tax policy can provide some of the missing insurance to consumers.

#### 4.1 State-Contingent Taxes

Figure 3 shows the impulse responses to the same negative productivity shock as previously for  $\tau^a \in \{1, 0, -1\}$ , keeping the current account restriction fixed at the baseline value of 5 percent. Thus, the government either holds labor taxes constant or it raises (decreases) them one-for-one with productivity shocks. A cyclical labor tax policy has direct effect on hours worked and output. If the government cuts taxes in low-productivity states and vice versa, households know that the labor tax will be temporarily low if productivity is low, providing them with an incentive to work more. The households' liquidity increases, such that the liquidity constraint becomes less binding and households

can borrow more or liquidate more of their assets. Households can increase consumption and investment due to higher domestic output and less severe financial constraints.

These results indicate that the government may be able to alleviate the frictions caused by liquidity constraints by conducting a cyclical tax policy, leading to potential welfare gains from such a policy. However, there is an opposite effect discussed by Barro (1979): the welfare cost of distortionary taxation is approximately quadratic in the level of taxes, such that intertemporal tax distortions due to fluctuating tax rates may limit the welfare gains from state-contingent tax policy. The welfare impact of cyclical tax policy thus seems ambiguous. Hence, I conduct detailed welfare comparisons in the following sub-section.

## 4.2 Optimal Policy

This section compares the optimal tax feedback coefficients for alternative assumptions on the tightness of the current account restriction. The optimization is done over the representative household's modified objective<sup>19</sup>

$$W_0 \equiv E_0 \sum_{t=0}^{\infty} \gamma_t [U(c_t, 1 - n_t) - P(d_t, n_t, d_{t-1}, k_{t-1})].$$

The optimal feedback coefficients  $\tau^{a*}$  maximize  $W_0$  for a given initial state of the economy, which is fixed under all possible policies. Computing welfare at the same initial state ensures that the economy begins at the same point under all policies and borrowing limits. This implies that the dynamic transitional effects of policy changes are correctly captured, see Kim, Kim, and Levin (2003), and Schmitt-Grohé and Uribe (2007).

That initial state could in principle be any point in the state space. However, I compute a second-order approximation of  $W_0$  evaluated at a point where the productivity shock is one standard deviation below its unconditional mean, whereas all endogenous variables are equal to their deterministic steady state values. This is consistent with Argentina's experience during the 1999-2002 economic crisis, since we are proxying a situation in which liquidity constraints become relevant due to an adverse shock. Our model can provide guidance on appropriate policy actions in a situation of this type.

The main results are documented in Figure 4 and Table 3. Figure 4 shows the computed values of  $W_0$  under state-contingent labor taxes, varying both the tightness of the current account restriction and the tax feedback coefficient. Table 3 reports the optimal state-contingent tax policies that reach the maximum level of welfare, together with a selection of implied business cycle statistics. For convenience, the table also reports the corresponding statistics under the constant tax policy from Table 2. We can observe that an increase in the tightness of the current account restriction leads to an overall decrease in welfare. The reason is the lack of consumption smoothing under

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<sup>19</sup>The adoption of the modified objective in deriving the optimal policy is appropriate, since this is the object that consumers are maximizing. However, the inclusion of the penalty function may blur welfare comparisons. As a check, Section 5 therefore also compares welfare under alternative policies using the original objective  $V_0$  defined in equation (1).

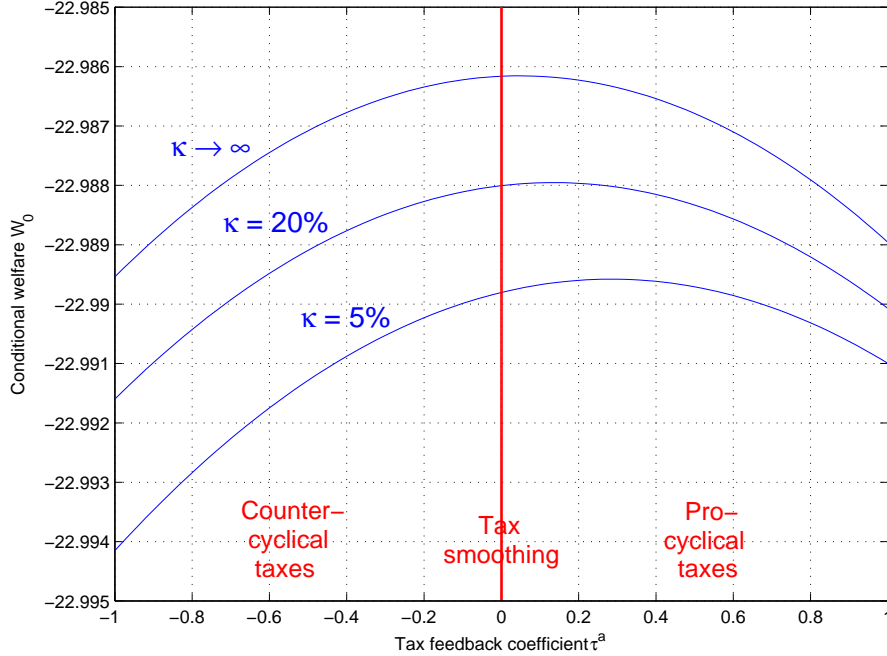


Figure 4: Conditional welfare under alternative policies. *Notes.* Vertical axis: second-order approximation of conditional welfare  $W_0$ ; horizontal axis: tax feedback coefficient  $\tau^a$ .

limited access to external finance, together with the additional distortions in the labor supply decision caused by the current account constraint.

The optimal state-contingent labor tax policy has a small positive feedback coefficient of 0.048 in the frictionless case, *i.e.* when  $\kappa \rightarrow \infty$ . The optimal labor tax is then close to constant, consistent with Barro's (1979) tax smoothing advice. However, labor taxes should be more procyclical the tighter the current account restriction. Under the mild restriction ( $\kappa = 20\%$ ) the optimal feedback coefficient is 0.135. In the baseline case ( $\kappa = 5\%$ ) welfare is maximized by a comparably strong cyclical labor tax policy. The optimal feedback coefficient is then 0.285. The channel through which the welfare effects occur is through a reduction in macroeconomic volatility, notably the variability of consumption, due to directed efforts against the (labor supply) distortions caused by the current account restriction. Furthermore, the procyclicality of consumption decreases under the optimal state-contingent labor tax.

Hence, these results indicate that optimal tax rates on labor income must not follow the standard tax smoothing advice in an environment where financial frictions are relevant, whereas they tend to do so in a frictionless environment. Labor taxes in small open economies should be more procyclical the bigger the importance of liquidity constraints. The stabilization gains from state-contingent labor taxes then outweigh the losses from intertemporal tax distortions. If consumers' possibilities to self-insure against productivity risks are limited, a government can step in and provide some of the missing insurance,

Table 3: Business cycles under constant-tax policy and optimal state-contingent policy.

<i>Type of policy</i> <sup>a</sup>	$\kappa \rightarrow \infty$		$\kappa = 20\%$		$\kappa = 5\%$	
	CT	ST	CT	ST	CT	ST
<i>Optimized rule <math>\tau^{a*}</math></i>	–	0.048	–	0.135	–	0.285
<i>Standard deviations</i> <sup>b</sup>						
Output	4.5	4.4	4.1	3.8	3.7	3.1
Consumption	0.9	0.9	1.2	1.1	1.6	1.3
Hours worked	3.4	3.3	2.8	2.5	2.2	1.5
Investment	4.1	4.0	8.8	8.2	10.5	8.9
Current account / GDP	3.3	3.2	1.7	1.6	0.6	0.5
Trade balance / GDP	3.8	3.8	2.5	2.3	1.5	1.3
Labor tax rate	–	0.7	–	2.1	–	4.3
<i>Correlations with output</i>						
Consumption	0.32	0.30	0.49	0.47	0.69	0.67
Hours worked	0.98	0.98	0.95	0.93	0.91	0.81
Investment	0.59	0.59	0.84	0.84	0.90	0.90
Current account / GDP	0.92	0.92	0.83	0.83	0.76	0.77
Trade balance / GDP	0.99	0.99	0.88	0.88	0.65	0.66

<sup>a</sup> CT denotes constant-tax policy and ST denotes optimal state-contingent tax policy.

<sup>b</sup> Standard deviations are measured in percent per year, and computed as coefficients of variation for output, consumption, hours worked, investment, and the labor tax rate.

even if distortionary taxes are its only policy instrument.

Under the given policy rule, a feedback coefficient of about 30 percent implies that labor tax rates fluctuate between approximately 16 percent and 12 percent per year around the average tax rate of 14 percent, for the baseline values of  $\sigma_\varepsilon$  and  $\rho$ . These values are empirically plausible given the variability of actual tax rates of approximately 5–10 percent per year (see Kim and Kim, 2005), and they also seem politically feasible.

## 5 Sensitivity Analysis

This section analyzes the sensitivity of the results documented above to alternative modeling assumptions. Three types of checks are performed on (i) the tax feedback rule, (ii) the type of objective function, and (iii) the specification of the penalty function.

### 5.1 Feedback Rule

One may argue that the government may not be able to observe the current state of productivity. Instead, it may only be able to do so with a lag. For instance, estimates

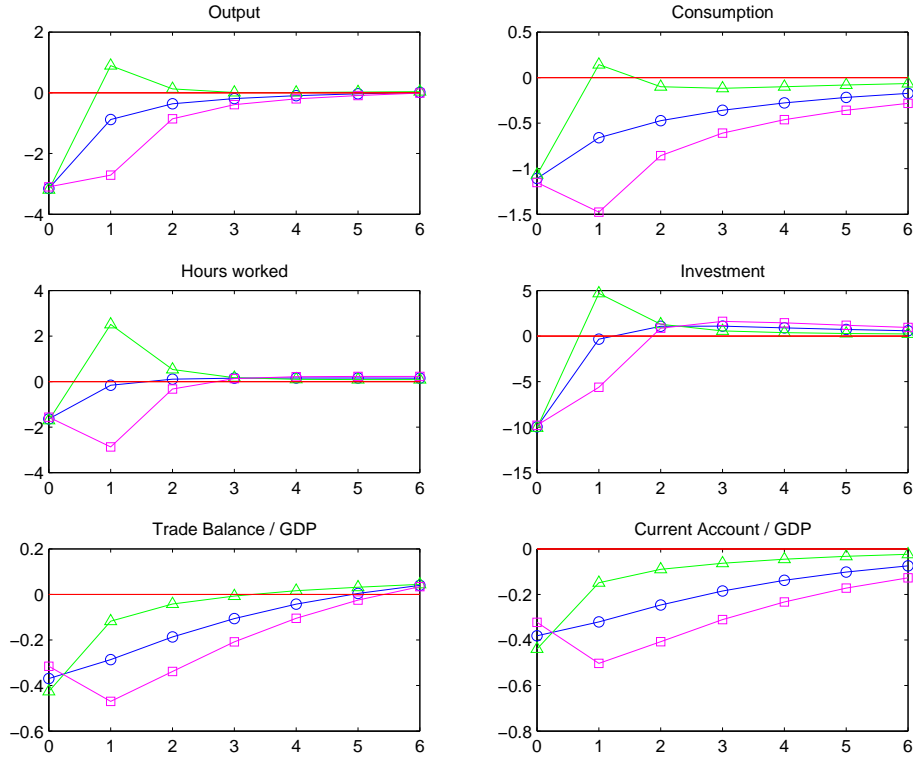


Figure 5: Impulse responses to negative one-standard deviation productivity shock under lagged productivity rule, for  $\kappa = 5\%$ . *Notes.* Vertical axes: percentage deviations from deterministic steady state; horizontal axes: years after shock. Circles: constant taxes; triangles:  $\tau^a = 1$ ; squares:  $\tau^a = -1$ .

of total factor productivity in a Solow residual regression can only be computed when data on labor and capital input become available, which usually happens with a time lag of one year. This section therefore checks the sensitivity of the results on the optimal state-contingent tax policy to a modification of the policy rule that takes  $a_{t-1}$  instead of  $a_t$  as a feedback variable in equation (14), as in Chen (2003).

Figure 5 plots the impulse response functions under this lagged productivity rule. The responses are again due to a negative one-standard deviation shock to productivity, and results are reported for the baseline calibration where  $\kappa = 5\%$ . Except for their savings decision, consumers do not react in a substantial manner to the future tax cut (raise) in period 0, such that the impact responses of the major macroeconomic aggregates under a state-contingent tax policy differ significantly from the constant-tax case. Above one year after the shock, however, the differences to the constant-tax policy are larger than under the current-productivity rule. Notice in particular that a procyclical tax policy of the same strength as previously leads to a substantial increase in hours worked, investment, output, and consumption in period 1. It thus appears that



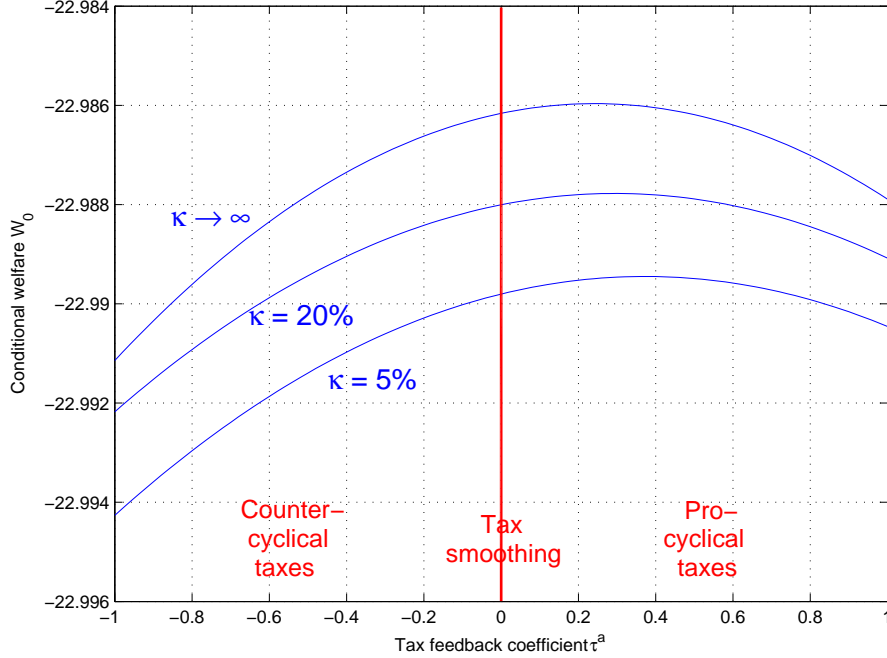


Figure 6: Conditional welfare under lagged productivity rule. *Notes.* Vertical axis: second-order approximation of conditional welfare  $W_0$ ; horizontal axis: tax feedback coefficient  $\tau^a$ .

a cyclical tax policy that reacts to with a lag to changes in the state of the economy can be equally effective in reducing macroeconomic fluctuations.

The welfare impact of state-contingent labor taxes under the lagged productivity rule is compared in Figure 6. One difference to Figure 4 is that the optimal tax rate is now further away from a constant one in the frictionless case. The size of the optimal feedback coefficients is also larger for  $\kappa = 20\%$  and  $\kappa = 5\%$ . The general result, however, remains unchanged if taxes reacts to productivity shocks with a lag: labor taxes should be more procyclical the tighter the current account constraint.

## 5.2 Objective Function

I have argued above that it is appropriate to adopt the modified objective  $W_0$ , which includes the penalty function, since this is the object that consumers are maximizing. However, the inclusion of the penalty function may blur welfare comparisons. Figure 7 therefore plots conditional welfare according to the original objective  $V_0$  defined in equation (1). The results are quantitatively very similar to the case when  $W_0$  is considered as the objective function. This is actually not very surprising, since the penalty function is calibrated in a way that makes  $W_0$  almost equivalent to  $V_0$  in a small neighborhood of the deterministic steady state, where welfare under alternative policies is evaluated. Hence, the results on the optimal state-contingent tax policy are not driven

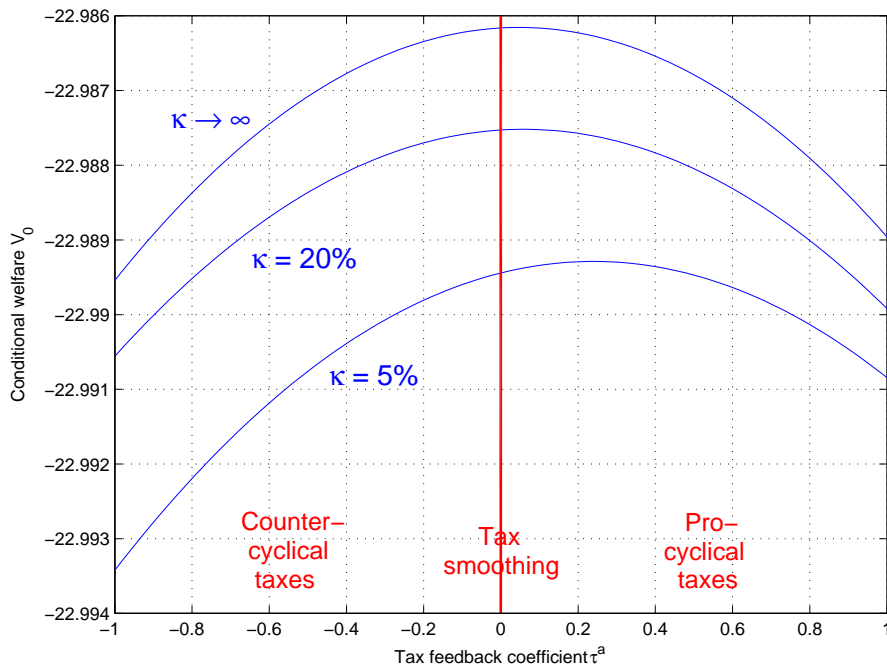


Figure 7: Conditional welfare according to original objective. *Notes.* Vertical axis: second-order approximation of conditional welfare  $V_0$ ; horizontal axis: tax feedback coefficient  $\tau^a$ .

by the specific choice of the objective function.

### 5.3 Penalty Function

Finally, let us compare the sensitivity of the results to variations in the curvature of the penalty function. In fact, evidence discussed by den Haan and de Wind (2008) indicates that a model with a non-linear penalty function can be solved with low-order perturbation up to a satisfactory degree of accuracy only if the curvature of the penalty function is not too high. On the other hand, the approximation of the original model with inequality constraint tends to be better with a relatively high curvature of the penalty function. Therefore, I compare the optimal state-contingent tax policy for two different versions of the model, one with a relatively low curvature of  $\eta_0 = 10$ , and one with a relatively high curvature of  $\eta_0 = 100$ .

Figure 8 reports the results. Both shape and location of the graph that corresponds to the frictionless case ( $\kappa \rightarrow \infty$ ) are virtually identical for both versions of the model, and there are only small differences for the tight restriction ( $\kappa = 5\%$ ). However, the graph corresponding to the mild restriction ( $\kappa = 20\%$ ) is shifted towards the right (left) in the low-curvature (high-curvature) model. In the first case, a rather flat penalty function makes the current account restriction have an impact on the allocation already far away from the point in the state space where it would turn binding in the original model. In

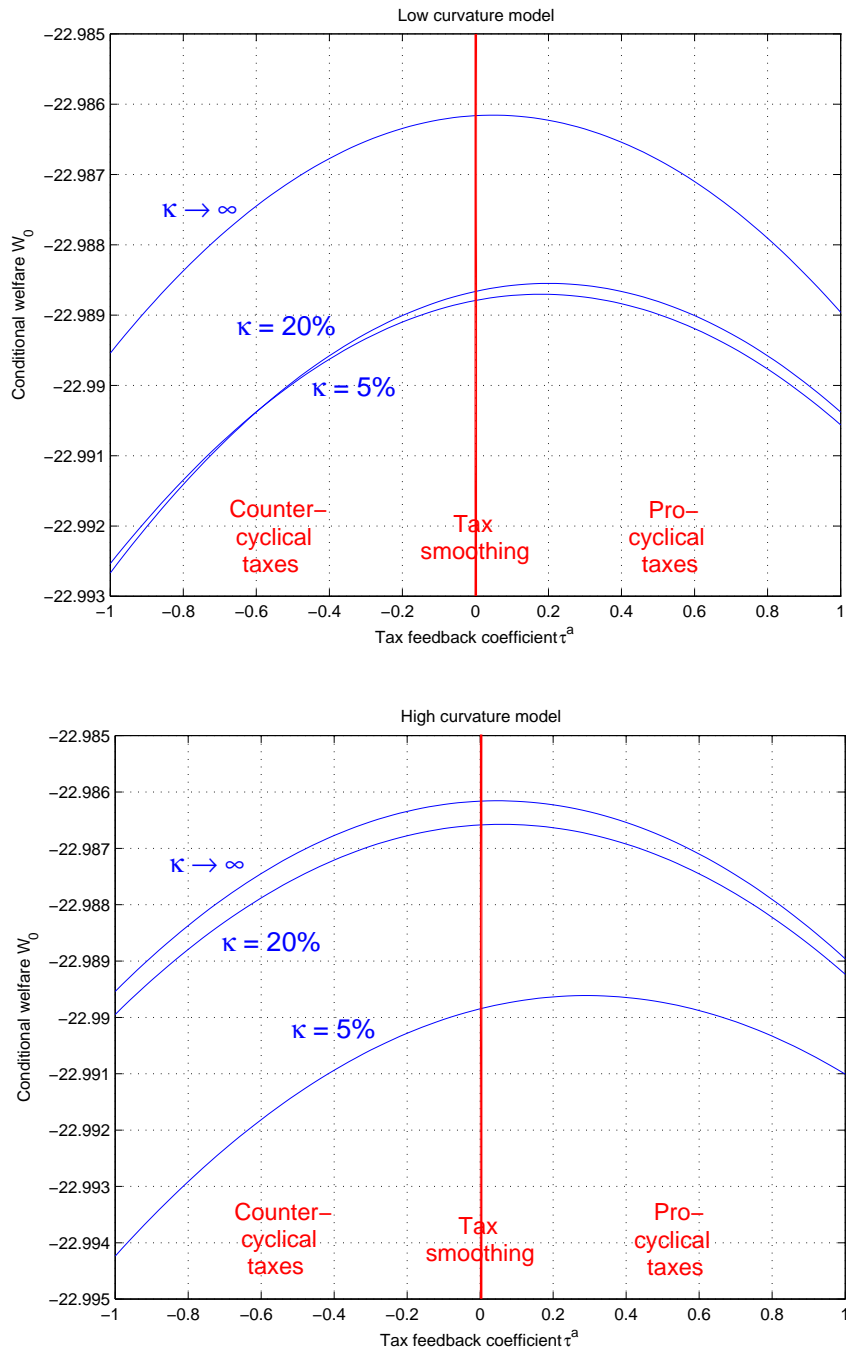


Figure 8: Conditional welfare for model with low curvature ( $\eta_0 = 10$ ) and high curvature ( $\eta_0 = 100$ ). *Notes.* Upper panel: low-curvature model; lower panel: high-curvature model; vertical axes: second-order approximation of conditional welfare  $W_0$ ; horizontal axes: tax feedback coefficient  $\tau^a$ .

the second case, the penalty function is relatively steep at the constraint such that the current account restriction only has an impact at points close to where it turns binding. These findings are an obvious implication of the penalty function approximation, and it appears that a value of  $\eta_0 = 50$  strikes a good compromise between the two extremes. The fact that the results on the optimal state-contingent tax policy are very similar for the baseline case provides us with some confidence on the quality of the approximation.

## 6 Conclusion

This paper has investigated the scope of state-contingent tax policy in a small open economy RBC model with liquidity constraints on the consumer side. I have shown that optimal tax rates on labor income do not follow the conventional tax smoothing advice in this environment. If consumers' possibilities to self-insure against productivity risks are limited, a government can step in and provide some of the missing insurance, even if distortionary taxes are its only policy instrument. The stabilization gains from state-contingent taxes then outweigh the losses from intertemporal tax distortions.

A main contribution of the paper is to add a fiscal perspective to the literature that analyzes the implications of financial vulnerabilities for monetary policy (see Tovar, 2008, for an overview). Although the focus of the paper is on emerging market economies, the fiscal policy implications of the results also extend to developed economies. In fact, many governments have adopted fiscal stimulus packages in the wake of the recent financial turmoil. However, the effectiveness of expansive fiscal policies is debatable both theoretically and empirically.<sup>20</sup> In a recent contribution, Forni, Monteforte, and Sessa (2007) demonstrate that government purchases of goods and services have small effects on private consumption in the euro area, whereas decreases in labor income and consumption tax rates have a sizeable effect on consumption and output. The link to the results of this paper should be obvious.

The paper has however two major shortcomings. First, the liquidity requirement considered is imposed without explicit micro-foundations. Introducing financial frictions without explicitly modeling contractual relationships between borrowers and lenders has a long history in the literature.<sup>21</sup> This way of proceeding should be seen as a simplifying device to give financial frictions the relevance in macroeconomic models that we do observe in reality. Furthermore, the flow borrowing constraint that results from the liquidity requirement considered in this paper has a clear empirical interpretation. It would nevertheless be desirable to derive a link between credit and real activity from first principles. For instance, one may argue that the empirical relevance of financial frictions stems from the producer side rather than the consumer side. Adverse effects of financial frictions on investment and output are difficult to obtain from the consumer side only, but if firms have restricted access to working capital factor allocations are distorted in times of financial distress (see Bernanke, Gertler, and Gilchrist, 1999). Thus, it would

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<sup>20</sup>See Galí, López-Salido, and Vallés (2007), Monacelli and Perotti (2007), and Ramey (2008).

<sup>21</sup>See for instance Kiyotaki and Moore (1997; 2008), Arellano and Mendoza (2002), Mendoza (2002; 2008), and Iacoviello (2005).

be interesting to investigate fiscal policy issues in a model that incorporates a link of this type between financial conditions and the real side of the economy.

Second, the way in which optimal tax policy is investigated is not fully rigorous. Since the aim is to focus squarely on the interaction of tax distortions and financial frictions, the use of simple tax feedback rules to evaluate alternative tax policies seems justified. The rigorous way to deal with optimal fiscal policy would be an application of the Ramsey approach to optimal taxation under exogenous revenue targets and public debt. Without any restrictions on government debt, however, a Ramsey planner could simply avoid the restriction on private debt by borrowing abroad and redistributing the revenue to domestic households. In order to make the question of optimal fiscal policy interesting, the model would therefore have to feature a more elaborate description of the government sector, including internal and external capital market imperfections. For example, if the government has easier access to external finance than domestic households, the results of this paper may survive. Both of these possibilities are left for future research.

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