Prudential Policy For Peggers*

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Abstract

This paper shows that in a small open economy with downward nominal wage rigidity pegging the nominal exchange rate creates a pecuniary externality. The externality causes unemployment, overborrowing, and depressed consumption. Ramsey optimal capital controls are shown to be prudential in the sense that they tax capital inflows in good times and subsidize external borrowing in bad times. Under plausible calibrations, this type of macro prudential policy is shown to lower the average unemployment rate by 10 percentage points, to reduce average external debt by 10 to 50 percent, and to increase welfare by 2 to 5 percent of consumption per period.

JEL Classifications: F41, E31, E62.
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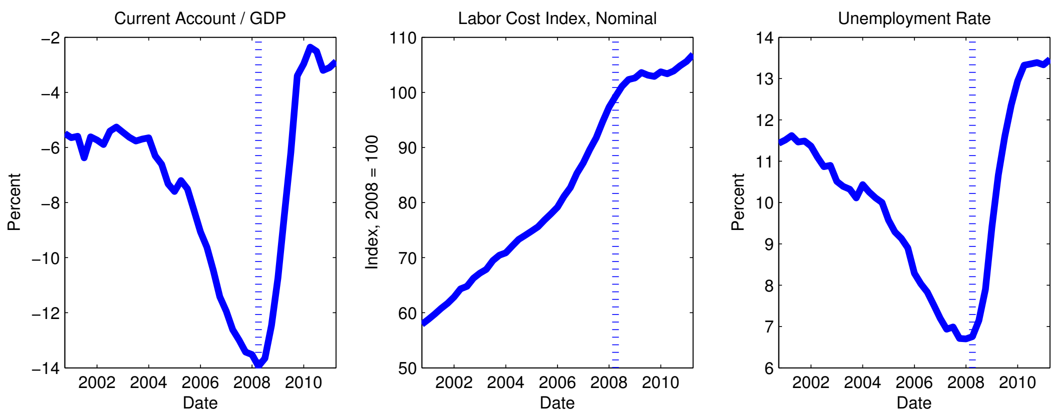
1 Introduction

Fixed-exchange rate arrangements are often part of broader economic reform programs that include liberalization of international capital flows. For small emerging economies, such a policy combination has been a mixed blessing. A case in point is the European currency union, which imposes capital account liberalization as a prerequisite for admission. Figure 1 displays the average current-account-to-GDP ratio, an index of nominal hourly wages in Euros, and the rate of unemployment for a group of peripheral European countries that are either on or pegging to the Euro over the period 2000 to 2011. In the early 2000s, these countries enjoyed large capital inflows, which through their expansionary effect on domestic absorption, led to sizable appreciations in hourly wages. With the onset of the

Figure 1: Boom-Bust Cycle in Peripheral Europe: 2000-2011



Data Source: Eurostat. Data represents arithmetic mean of Bulgaria, Cyprus, Estonia, Greece, Lithuania, Latvia, Portugal, Spain, Slovenia, and Slovakia.

global recession in 2008, however, capital inflows dried up and aggregate demand collapsed. At the same time nominal wages remained at the level they had achieved at the peak of the boom. The combination of depressed levels of aggregate demand and high nominal wages was associated with a massive increase in involuntary unemployment. In turn, local monetary authorities were unable to reduce real wages via a devaluation because of their commitment to the currency union.

This narrative evokes several interrelated questions. One is what is the connection between capital mobility and the economic performance of fixed exchange rate regimes. Another is whether emerging-country peggers might be better off imposing capital controls. And, if so, whether optimal capital controls are prudential in nature. The goal of this paper is to address these questions in the context of a dynamic, stochastic, optimizing model of an emerging economy. The central counterfactual situation considered in our analysis, i.e., the imposition of capital controls, serves as a way to highlight the costs imposed by the current institutional arrangement in the European Union that insists on free capital mobility. The main point that emerges from our analysis is that the combination of free capital mobility and currency pegs is highly deleterious for peripheral members of the union.

Our theoretical laboratory is the Schmitt-Grohé and Uribe (2011a) model of an open economy with tradable and nontradable goods, downward nominal wage rigidity and a fixed exchange rate. The model economy is driven by exogenous and stochastic disturbances to the endowment of tradable goods and to the country interest rate. We show that in the context of this model, the combination of downward nominal wage rigidity, a fixed exchange rate, and free capital mobility creates a negative pecuniary externality. The nature of this externality is that expansions in aggregate demand drive up wages, putting the economy in a vulnerable situation. For in the contractionary phase of the cycle, downward nominal wage rigidity and a fixed exchange rate prevent real wages from falling to the level consistent with full employment. Agents understand this mechanism, but are too small to internalize the fact that their individual expenditure decisions collectively cause inefficiently large increases in wages during expansions, which exacerbate unemployment during contractions.

The existence of the pecuniary externality creates a rationale for government intervention. We focus on capital controls as a second-best instrument. In particular, we assume that the government levies a proportional tax (subsidy) on net external debt holdings. The tax is equivalent to an interest rate markup on net foreign liabilities. We then characterize analytically and numerically optimal capital control policy under commitment. We show that the Ramsey-optimal tax on external debt is positive on average and highly procyclical. Thus, the optimal capital control policy is prudential in nature, as it restricts capital inflows in good times and subsidizes external borrowing in bad times.

In our model, a benevolent government has an incentive to levy taxes on external debt during expansions as a way to limit nominal wage growth. Moderating wage growth during booms helps ameliorate the unemployment problem caused by downward wage rigidity during contractions. In turn, capital controls affect wage growth through their effect on the aggregate absorption of tradable goods. In our small open economy, consumption of tradables acts as a shifter of the demand for nontradables. As a result, the government can indirectly affect employment in the nontraded sector by manipulating the intertemporal price of tradables (the interest rate) via capital controls. Thus, the government in a fixed-exchange-rate economy determines the optimal capital control policy as the solution to a tradeoff between intertemporal distortions (caused the capital controls themselves) and static distortions (caused by downward real wage rigidity).

Importantly, the optimal capital control policy implied by our model does not belong to the class of beggar-thy-neighbor policies. For it does not seek to increase foreign demand for domestic goods during crises. On the contrary, the optimal capital control policy in our model is one in which during crises the government subsidizes domestic absorption of tradable goods, thereby discouraging exports. The reason why the government has incentives to stimulate imports during downturns is that greater domestic absorption of tradables increases demand for nontradables, thereby reducing unemployment in the nontraded sector.

Versions of the model calibrated to Argentina, Greece, and Spain show that the optimal capital control policy achieves significant reductions in unemployment (about 10 percentage points) and that the welfare gains from macro prudential policy are large, between 2 and 5 percent of consumption per period.

Further, we find that free capital mobility induces peggers to overborrow. Specifically, for our baseline calibration, the average external debt-to-output ratio in the economy with free capital mobility is more than twice as large as the one induced under optimal capital controls.

Capital controls are not the only instruments through which the policymaker can address the inefficiencies arising from the combination of a currency peg and downward nominal wage rigidity. The most natural instrument to address nominal rigidities would be monetary policy, that is, devaluations. Another natural policy avenue would be the use of fiscal policy targeted at the labor market. Thirdly, downward nominal wage rigidity could be disarmed by an appropriate increase in eurowide inflation. We have shown elsewhere that the first-best allocation can indeed be achieved by means of optimal devaluations or by labor or consumption subsidies (Schmitt-Grohé and Uribe; 2011a, 2012b), or by raising the Euro-area inflation target (Schmitt-Grohé and Uribe; 2012c). A natural question is then why bother characterizing optimal capital controls, if, after all, they achieve only a second-best allocation. The reason is that policymakers may find that capital controls is the only instrument that they can implement in practice. For many eurozone countries, and for reasons that may exceed economic considerations, devaluing is not an option. In addition, the use of labor subsidies to achieve the first best may be difficult from a political point of view. For instance, in Schmitt-Grohé and Uribe (2011a, 2012b) we show that the labor subsidy scheme that implements the first best inherits the stochastic properties of the underlying shocks, which in emerging countries like those in the periphery of Europe, are highly volatile. Thus the optimal labor subsidy scheme would require large variations in wage subsidies at a quarterly frequency. This may be highly problematic in light of the fact that the institutional arrangements (especially the legislative process) that govern the determination of income taxes is highly inertial, making large swings in labor subsidies on a quarter-to-quarter basis unrealistic. By contrast, capital controls can be politically portrayed as taxes on foreign speculators. As a result the executive branch of the government typically is given much more leeway to set capital-inflow taxes at business-cycle frequency. Finally, raising the Euro-area inflation target as a way to solve the unemployment problem in the periphery may not be viable because it conflicts with the inflation preferences of the core countries.

In the case of Europe, all four policy options for addressing the inefficiencies brought about by downward nominal wage rigidity, namely devaluation, labor/production subsidies, an increase in the ECB's inflation target, and capital controls, are limited by existing supranational arrangements. If peripheral Europe is to achieve stability central aspects of these arrangements are likely to change. It is therefore of interest to fully characterize the business-cycle implications of each of these four policy alternatives. The contribution of the current paper is to investigate the potential benefits of moving away from free capital mobility toward a policy of optimally designed capital controls.

We interpret capital controls in a broad sense as regulations of cross-border financial flows. For instance, Basel III contemplates the use of procyclical capital requirements for banks. This type of regulation is of interest because it tends to act like capital controls but without violating existing statutes governing the flow of financial capital across borders in the European Union.

We view our work as most closely related to the Mundellian literature on the trilemma of international finance, according to which a country cannot have at the same time a fixed exchange rate, free capital mobility, and an independent interest rate policy. (For a recent treatment, see Obstfeld et al., 2010.) We present an explicit articulation of this view in the context of a dynamic, optimizing model of a small open economy with downward nominal wage rigidity. We take a fixed exchange rate regime as a given, because we wish to understand the policy options available to the peripherical members of the eurozone short of breaking away from the common currency arrangement. In our model economy, the benevolent government has an incentive to vary the effective interest rate (through capital controls) as a way to insulate the nontraded sector from external shocks. The existing theoretical literature on optimal capital controls based on the trilemma of international finance is quite informal and reduced form. By contrast, the building blocks of our theoretical framework are welfare maximizing households, profit maximizing firms, and a benevolent government operating in a dynamic and uncertain environment. Consequently, our model, once calibrated to capture key elements of actual emerging economies, allows us to derive sharp predictions about the welfare-maximizing capital control process and its associated real allocation.

A second strand of the related literature stresses financial distortions, such as collateral constraints on external borrowing as a rationale for capital controls (Auernheimer and García-Saltos, 2000; Uribe, 2006, 2007; Lorenzoni, 2008; Korinek, 2010; Jeanne and Korinek, 2012; Benigno et al., 2011; and Bianchi, 2011). A third line of work is based on the classical trade theoretic argument that large countries can affect the interest rate, or the intertemporal price of consumption (e.g., Obstfeld and Rogoff, 1996 section 1.4, Schmitt-Grohé and Uribe, 2012a section 4.4, and Costinot et al., 2011). As a result, governments of large countries have incentives to apply capital controls as a means to induce households to internalize the country's market power in financial markets. Our theory of capital controls is distinct from the above two in that it does not assume the existence of collateral constraints or market power in financial markets. In a recent related paper, Farhi and Werning (2012) study capital controls in the context of a perfect-foresight, linearized version of the Galí and Monacelli (2005) sticky-price model.

The remainder of the paper is organized as follows. Section 2 embeds capital controls into a small open economy model with downward nominal wage rigidity and a fixed-exchange rate. Section 3 characterizes optimal capital control policy under commitment. Section 4 shows analytically that optimal capital controls are prudential. Section 5 calibrates the model to the Argentine economy. It analyzes quantitatively the behavior of the economy with and without capital controls undergoing a boom-bust cycle. Section 6 presents the effects of optimal capital controls on first and second unconditional moments of key macroeconomic aggregates. Section 7 identifies and quantifies overborrowing induced by the combination of a currency peg and downward nominal wage rigidity. Section 8 investigates the welfare losses due to free capital mobility in fixed exchange rate economies. Section 10 shows that our main results are robust to using data from Greece and Spain in the econometric estimation of the exogenous driving forces. Section 11 concludes.

2 An Open Economy With Downward Wage Rigidity

We embed capital controls into the small open economy model with downward nominal wage rigidity developed in Schmitt-Grohé and Uribe (2011a). We assume that the nominal wage rate, denoted W_t, must satisfy the following restriction

$$W_t \geq \gamma W_{t-1}, \tag{1}$$

where γ is a nonnegative parameter governing the degree of downward nominal wage rigidity. The larger is γ, the more stringent is the downward rigidity in nominal wages. In Schmitt-

Grohé and Uribe (2011a), we present empirical evidence suggesting that γ is close to unity.

Throughout the present analysis, we assume that the central bank pegs the nominal exchange rate. Specifically, letting E_t denote the domestic-currency price of one unit of foreign currency, we impose

$$E_t = \bar{E} \tag{2}$$

for all t, where $\bar{E}$ is a positive constant. The combination of a fixed-exchange-rate regime and downward nominal wage rigidity introduces a real rigidity. Specifically, the wage rate in terms of foreign currency, denoted $w_t \equiv W_t/E_t$ is downwardly rigid. This rigidity makes the economy vulnerable to any shock that requires a fall in real wages. The inability of the real wage to fall will in general cause unemployment and therefore a loss of welfare.

The inefficiency introduced by the combination of downward nominal wage rigidity and a fixed exchange rate opens the door to welfare-improving fiscal policy. In the present investigation, we characterize the Ramsey optimal capital control policy to study the extent to which capital controls can help ameliorate the aforementioned inefficiency.[1] We model capital controls as a proportional tax on net external debt.

The model features two types of good, tradables and nontradables. Tradable output is exogenous and stochastic, while nontraded output is produced with labor services. The economy is driven by two exogenous shocks. One is the endowment of tradables just described. The second shock emerges from the assumption that the interest rate charged to the small open economy in international financial markets is exogenous and stochastic.

2.1 Households

The economy is populated by a large number of identical households with preferences described by the utility function

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(c_t), \tag{3}$$

where c_t denotes consumption. The period utility function U is assumed to be strictly increasing and strictly concave and the parameter β, denoting the subjective discount factor resides in the interval $(0,1)$. The symbol $\mathbb{E}_t$ denotes the mathematical expectations operator conditional upon information available in period t. The consumption good is a composite of tradable consumption, c_t^T, and nontradable consumption, c_t^N. The aggregation technology is of the form

$$c_t = A(c_t^T, c_t^N), \tag{4}$$

[1]The Ramsey optimal allocation attained with capital controls can also be achieved via a proportional tax on consumption. For details, see the last paragraph of section 3.

where A is an increasing, concave, and linearly homogeneous function.

We assume full liability dollarization. Specifically, households have access to a one-period, internationally traded, state non-contingent bond denominated in tradables. We let d_t denote the level of debt assumed in period $t-1$ and due in period t and r_t the interest rate on debt held between periods t and $t+1$. The sequential budget constraint of the household is given by

$$c_t^T + p_t c_t^N + d_t = (1+\tau_t^y)[y_t^T + w_t h_t + \phi_t] + \frac{d_{t+1}(1-\tau_t^d)}{1+r_t}, \tag{5}$$

where p_t denotes the relative price of nontradables in terms of tradables, τ_t^y denotes a proportional income subsidy rate (tax rate if negative), y_t^T denotes the endowment of tradable goods, h_t denotes hours worked, ϕ_t denotes profits from the ownership of firms, and τ_t^d denotes the tax rate on debt acquired in period t.

The relative price of nontradables in terms of tradables, p_t, is given by P_t^N/P_t^T, where P_t^N and P_t^T, denote, respectively, the nominal prices of nontradables and tradables. We assume that the law of one price holds for tradables. Specifically, we let P_t^{T*} denote the foreign currency price of tradables. Then, the law of one price implies that

$$P_t^T = P_t^{T*} E_t.$$

We assume that the foreign-currency price of tradables is constant and normalized to unity, $P_t^{T*} = 1$.

The government intervention in the international financial market through the capital control variable τ_t^d alters the effective gross interest rate paid by the household from $1+r_t$ to $(1+r_t)/(1-\tau_t^d)$. The rate τ_t^d can take positive or negative values. When it is positive, the government discourages borrowing by raising the effective interest rate. In this case, we say that the government imposes capital controls. On the other hand, when τ_t^d is negative, the government subsidizes international borrowing by lowering the effective interest rate. As we will see shortly, a benevolent government will make heavy use of cyclical adjustments in capital controls to stabilize consumption and employment.

Households supply inelastically $\bar{h}$ hours to the labor market each period. However, because of the presence of downward nominal wage rigidity, they may not be able to sell all of the hours supplied. As a result, households take employment, $h_t \leq \bar{h}$, as exogenously given.

The income tax rate τ_t^y serves as a channel for the government to rebate the fiscal revenues created by the imposition of capital controls. Because all of the components of nonfinancial individual income, namely, y_t^T, $w_t h_t$, and ϕ_t, are taken as exogenous by the household, the income tax τ_t^y is nondistorting.

Households are assumed to be subject to the following debt limit, which prevents them from engaging in Ponzi schemes

$$d_{t+1} \leq \bar{d}, \tag{6}$$

where $\bar{d}$ denotes the natural debt limit. Households choose contingent plans $\{c_t, c_t^T, c_t^N, d_{t+1}\}$ to maximize (3) subject to (4)-(6) taking as given w_t, h_t, ϕ_t, y_t^T, r_t, τ_t^d, τ_t^y, and p_t. The optimality conditions associated with this problem are (4)-(6) and

$$\frac{A_2(c_t^T, c_t^N)}{A_1(c_t^T, c_t^N)} = p_t, \tag{7}$$

$$\lambda_t = U'(c_t) A_1(c_t^T, c_t^N),$$

$$\frac{\lambda_t(1 - \tau_t^d)}{1 + r_t} = \beta \mathbb{E}_t \lambda_{t+1} + \mu_t,$$

$$\mu_t \geq 0,$$

$$\mu_t(d_{t+1} - \bar{d}) = 0,$$

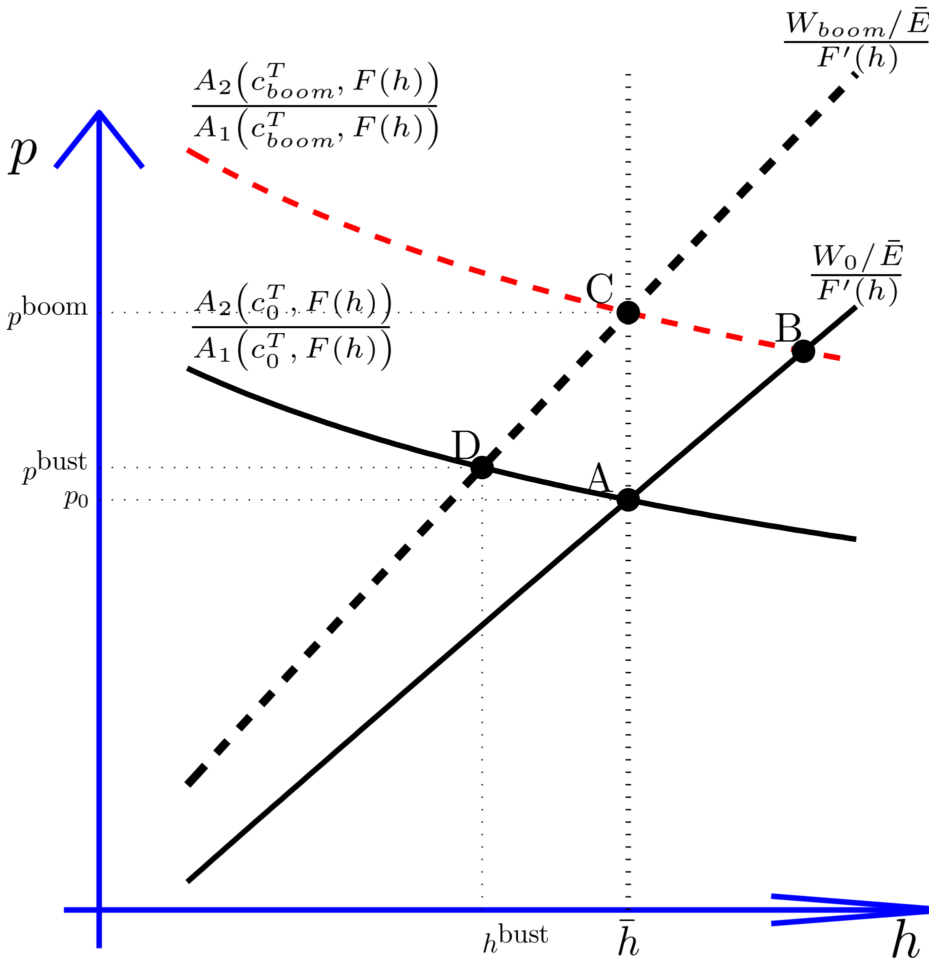
where λ_t and μ_t denote the Lagrange multipliers associated with (5) and (6), respectively.

Equation (7) describes the demand for nontradables as a function of the relative price of nontradables, p_t, and the level of tradable absorption, c_t^T. Given c_t^T, the demand for nontradables is strictly decreasing in p_t. This is a consequence of the assumptions made about the aggregator function A. It reflects the fact that as the relative price of nontradables increases, households tend to consume relatively less nontradables. The demand function for nontradables is depicted in figure 2 as a downward sloping solid line. (Notice that in the figure, the demand function is plotted in the space (h_t, p_t), rather than in the space (c_t^N, p_t). As will become clear shortly, we are jumping ahead and using the fact that under market clearing in the nontraded sector, $c_t^N = F(h_t)$ at all times. We refer to the depicted locus as the demand function for nontradables, even though strictly speaking it is not.) An increase in the absorption of tradables shifts the demand schedule up and to the right, reflecting normality. This shift is shown with a dashed downward sloping line in figure 2, for an increase in traded consumption from c_0^T to c_{boom}^T. It follows that absorption of tradables can be viewed as a shifter of the derived demand for labor. Of course, c_t^T is itself an endogenous variable, which is determined simultaneously with all other endogenous variables of the model.

2.2 Firms

Nontraded output is produced by perfectly competitive firms. Each firm operates a production technology given by $F(h_t)$, which uses labor services as the sole input. The function F is assumed to be strictly increasing and strictly concave. Firms choose the amount of labor

Figure 2: Peg-Induced Pecuniary Externality



input to maximize profits, given by

$$\phi_t \equiv p_t F(h_t) - w_t h_t.$$

The optimality condition associated with this problem is

$$p_t F'(h_t) = w_t.$$

This condition represents the supply of nontradable goods. It is depicted with a solid upward sloping line in the space (h, p) in figure 2. Ceteris paribus, the higher is the relative price of the nontraded good, the higher is the demand for labor and therefore the larger the supply of nontradable goods. Also, all other things equal, the higher is the labor cost w_t, the smaller are the demand for labor and the supply of nontradables at each level of the relative price p_t. Figure 2 displays with a broken upward sloping line the shift in the supply schedule that results from an increase in the nominal wage rate from W_0 to $W_{boom} > W_0$, holding the nominal exchange rate constant at $\bar{E}$.

2.3 Closure of the Labor Market

The following three conditions must hold at all times:

$$w_t \geq \gamma w_{t-1},$$

$$h_t \leq \bar{h},$$

and

$$(h_t - \bar{h})(w_t - \gamma w_{t-1}) = 0.$$

The first two constraints were already introduced. The third is a slackness condition stating that whenever there is underemployment the lower bound on wages must bind, and that whenever this lower bound is not binding, the labor market must operate at full employment. We note that the assumed structure of the labor market is perfectly competitive. Both workers and employers are wage takers. Alternatively, one could assume market power on either side. In the related new Keynesian literature, it is customary to assume that workers have market power and set wages to maximize their lifetime utility. As emphasized by Elsby (2009), in the presence of a lower bound on nominal wages, this market structure might give rise to an endogenous compresion of wage incrreases in anticipation of future adverse shocks.

2.4 The Government

The government imposes a proportional tax (subsidy) on debt, τ_t^d, and a proportional subsidy (tax) on income, τ_t^y. Given τ_t^d, whose determination we will discuss shortly, the government sets income subsidies to balance the budget period by period. Specifically, τ_t^y satisfies

$$\tau_t^y(y_t^T + w_t h_t + \phi_t) = \tau_t^d \frac{d_{t+1}}{1+r_t}.$$

2.5 Non-Walrasian Equilibrium

Because product prices are assumed to be fully flexible, the market for nontraded goods must clear at all times. That is, the condition

$$c_t^N = F(h_t)$$

holds for all t. Combining this condition, the household's budget constraint, the government's budget constraint, and the definition of firms' profits, we obtain the following market-clearing condition for traded goods:

$$c_t^T + d_t = y_t^T + \frac{d_{t+1}}{1+r_t}. \tag{8}$$

The complete set of conditions describing the competitive disequilibrium dynamics is then given by (8) and

$$P(c_t^T, h_t)F'(h_t) = w_t, \tag{9}$$

$$h_t \leq \bar{h}, \tag{10}$$

$$w_t \geq \gamma w_{t-1}, \tag{11}$$

$$d_{t+1} \leq \bar{d}, \tag{12}$$

$$\lambda_t = U'(A(c_t^T, F(h_t)))A_1(c_t^T, F(h_t)), \tag{13}$$

$$\frac{\lambda_t(1-\tau_t^d)}{1+r_t} = \beta \mathbb{E}_t \lambda_{t+1} + \mu_t, \tag{14}$$

$$\mu_t \geq 0, \tag{15}$$

$$\mu_t(d_{t+1} - \bar{d}) = 0, \tag{16}$$

$$(h_t - \bar{h})(w_t - \gamma w_{t-1}) = 0, \tag{17}$$

$$\tau_t^y = \tau_t^d \frac{d_{t+1}/(1+r_t)}{y_t^T + P(c_t^T, h_t)F(h_t)}, \tag{18}$$

where

$$P(c_t^T, h_t) \equiv \frac{A_2(c_t^T, F(h_t))}{A_1(c_t^T, F(h_t))}$$

denotes the relative price of nontradables in terms of tradables expressed as a function of consumption of tradables and employment.

Notice that all markets except the labor market are in equilibrium. One might wonder whether this situation violates Walras' Law. The answer is that Walras' Law is not applicable in the current environment. The reason is that our model does not feature a Walrasian equilibrium. For Walras' Law to apply, it is necessary that the aggregate consolidated budget constraints of households and firms be equal to the value of excess demands. In our model this is not the case. For the budget constraint of the household, given in equation (5), is cast not in terms of its desired supply of labor, $\bar{h}$, but in terms of its realized employment, h_t. As a result, the fact that all but one market clear does not imply that the remaining one must also clear.

3 Ramsey Optimal Capital Controls

The combination of downward nominal wage rigidity and a currency peg creates a negative pecuniary externality. The nature of this externality is that in periods of economic expansion, elevated demand for nontradables drives real wages up placing the economy in a vulnerable situation. For in the contractionary phase of the cycle, downward nominal wage rigidity and the currency peg hinder the downward adjustment of real wages, causing unemployment. Individual agents understand this mechanism, but are too small to internalize the fact that their own expenditure choices collectively exacerbate disruptions in the labor market.

The pecuniary externality can be visualized in figure 2. The initial position of the economy is at point A, where the labor market is operating at full employment, $h_t = \bar{h}$. In response to a positive external shock, traded absorption increases from c_0^T to c_{boom}^T causing the demand function to shift up and to the right. If nominal wages stayed unchanged, the new intersection of the demand and supply schedules would occur at point B. However, at that point, employment would exceed the available supply of labor $\bar{h}$. The excess demand for labor drives up the nominal wage from W_0 to W_{boom} causing the supply of nontradables to shift up and to the left. The new intersection of the demand and supply schedules occurs at point C, where full employment is restored and the excess demand for labor has disappeared.

Suppose now that the external shock fades away, and that, therefore, absorption of tradables goes back to its original level c_0^T. The decline in c_t^T shifts the demand schedule back to its original position. However, the economy does not immediately return to point A, because, due to downward nominal wage rigidity, the nominal wage stays at W_{boom} and, as a result, the supply schedule does not move. The new intersection is at point D. There, the economy suffers involuntary unemployment equal to $\bar{h} - h_{bust}$. Over time, the economy will return to point A. However, the convergence is inefficient because it features unemployment throughout. Consequently, the government has an incentive to prudentially regulate capital flows to curb the initial expansion in tradable consumption in response to positive external shocks. Such policy would dampen the initial increase in nominal wages and in that way mitigate the subsequent unemployment problem as the economy returns to its initial state.

In the present study, we focus on a second-best type of government intervention that takes the form of capital controls. Specifically, we assume that the instruments available to the government are the tax rate on debt τ_t^d and the income subsidy τ_t^y. The latter tax is merely used as a vehicle to rebate in a nondistorting fashion the revenues generated by capital controls. The government is assumed to be benevolent and to be endowed with full commitment. We therefore refer to the fiscal authority as the Ramsey planner. It is worth noting that the battery of fiscal instruments available to our Ramsey planner is limited to capital controls, and, in particular, does not include wage-subsidy schemes in labor markets afflicted by downward wage rigidity. Elsewhere (Schmitt-Grohé and Uribe, 2011a, 2012b) we show that appropriately designed wage subsidies can fully eliminate the distortions arising from the combination of downward wage rigidity and a currency peg.

The Ramsey planner's optimization problem consists in choosing a tax scheme $\{\tau_t^d, \tau_t^y\}$ to maximize the household's lifetime utility function (3) subject to the complete set of conditions describing the competitive dynamics, equations (8)-(18). The strategy we follow to characterize the Ramsey allocation is to drop conditions (13)-(18) from the set of constraints of the Ramsey planner's problem and then to show that the solution to this less constrained problem satisfies the omitted constraints.

Accordingly, the Lagrangian of the less constrained Ramsey problem is given by

$$
\begin{aligned}
\mathcal{L} \;=\; & \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Big\{ U(A(c_t^T, F(h_t))) \\
& + \lambda_t^c \left[y_t^T + \frac{d_{t+1}}{1+r_t} - c_t^T - d_t \right] \\
& + \lambda_t^p \left[P(c_t^T, h_t) F'(h_t) - w_t \right] \\
& + \lambda_t^h \left[\bar{h} - h_t \right] \\
& + \lambda_t^w \left[w_t - \gamma w_{t-1} \right] \\
& + \lambda_t^d \left[\bar{d} - d_{t+1} \right] \Big\},
\end{aligned}
$$

where $\lambda_t^c > 0$, $\lambda_t^h \geq 0$, $\lambda_t^w \geq 0$, $\lambda_t^d \geq 0$, and λ_t^p are Lagrange multipliers.

The first-order optimality conditions with respect to λ_t^c, λ_t^p, λ_t^h, λ_t^w, λ_t^d, c_t^T, h_t, d_{t+1}, w_t, and associated slackness conditions are, respectively, (8)-(12) and

$$U'(A(c_t^T, F(h_t))A_1(c_t^T, F(h_t)) = \lambda_t^c - \lambda_t^p P_1(c_t^T, h_t)F'(h_t) \tag{19}$$

$$U'(A(c_t^T, F(h_t))A_2(c_t^T, F(h_t))F'(h_t) = \lambda_t^h - \lambda_t^p[P_2(c_t^T, h_t)F'(h_t) + P(c_t^T, h_t)F''(h_t)] \tag{20}$$

$$\frac{\lambda_t^c}{(1+r_t)} = \beta \mathbb{E}_t \lambda_{t+1}^c + \lambda_t^d \tag{21}$$

$$\lambda_t^w = \beta\gamma \mathbb{E}_t \lambda_{t+1}^w + \lambda_t^p \tag{22}$$

$$(h_t - \bar{h})\lambda_t^h = 0 \tag{23}$$

$$\lambda_t^w (w_t - \gamma w_{t-1}) = 0 \tag{24}$$

$$(d_{t+1} - \bar{d})\lambda_t^d = 0 \tag{25}$$

We now show that allocations $\{c_t^T, h_t, w_t\}$ that satisfy the optimality conditions of the less constrained Ramsey problem, that is, conditions (8)-(12) and (19)-(25), also satisfy the constraints that were omitted from the Ramsey problem, namely, conditions (13)-(18). To see this, first pick λ_t to satisfy (13). Next, set $\mu_t = 0$ for all t.[2] It follows that (15) and (16) are satisfied. Pick τ_t^d to satisfy (14). To ensure that the Ramsey policy is revenue neutral, pick τ_t^y to satisfy (18). It remains to be shown that the slackness condition (17) holds in the Ramsey equilibrium. To see that this is the case, consider the following proof by contradiction. Suppose, contrary to what we wish to show, that in the Ramsey allocation $h_t < \bar{h}$ and $w_t > \gamma w_{t-1}$ at some date t. Consider now an increase in hours only at date t from h_t to $\tilde{h}_t \leq \bar{h}$. Clearly, this perturbation does not violate (8). From (9) we have that the real wage falls to $\tilde{w}_t \equiv P(c_t^T, \tilde{h}_t)F'(\tilde{h}_t) < w_t$. Because P and F' are continuous functions, expression (11) is satisfied provided the increase in hours is sufficiently small. Starting in $t+1$, the Ramsey problem is less constrained because $\tilde{w}_t < w_t$. This shows that the perturbation is feasible. Finally, the perturbation is clearly welfare increasing because it raises the consumption of nontradables in period t without affecting the consumption of tradables in any period or the consumption of nontradables in any period other than t. It follows that an allocation that does not satisfy the slackness condition (17) cannot be a

[2]Note that in states in which the Ramsey allocation calls for setting $d_{t+1} < \bar{d}$, μ_t must be chosen to be zero. However, in states in which the Ramsey allocation yields $d_{t+1} = \bar{d}$, μ_t need not be chosen to be zero. In these states, any positive value of μ_t could be supported in the decentralization of the Ramsey equilibrium. Of course, in this case, τ_t^d will depend on the chosen value of μ_t. In particular, τ_t^d will be strictly decreasing in the arbitrarily chosen value of μ_t and will be smaller than the one given in equation (26).

solution to the less constrained Ramsey problem.[3]

From the arguments presented above, we have that the optimal capital control policy must deliver tax rates on debt satisfying

$$\tau_t^d = 1 - \beta(1+r_t)\frac{E_t U'(c_{t+1}) A_1(c_{t+1}^T, c_{t+1}^N)}{U'(c_t) A_1(c_t^T, c_t^N)}, \tag{26}$$

where c_t, c_t^T, and c_t^N denote the Ramsey-optimal processes of consumption, consumption of tradables, and consumption of nontradables, respectively. It follows from the above expression that, all other things equal, capital controls are larger the larger is the expected fall in the marginal utility of tradable consumption. That is, capital controls are more likely to be put into place when either total consumption or consumption of tradables or both are expected to grow.[4] Conversely, all other things equal, the Ramsey fiscal authority loosens capital restrictions when aggregate consumption or consumption of tradables or both are expected to decline.

An implication of the previous analysis is that one can characterize the Ramsey allocation as the solution to the following Bellman equation problem:

$$v(y_t^T, r_t, d_t, w_{t-1}) = \max \left[U(A(c_t^T, F(h_t)) + \beta \mathbb{E}_t v(y_{t+1}^T, r_{t+1}, d_{t+1}, w_t) \right] \tag{27}$$

subject to (8)-(12), where $v(y_t^T, r_t, d_t, w_{t-1})$ denotes the value function of the representative household. We exploit this formulation of the Ramsey problem in our numerical analysis.

It can be shown that the model with Ramsey optimal capital controls is equivalent to one in which a benevolent government chooses the level of external debt and households cannot participate in financial markets but are hand-to-mouth agents. In this formulation, households receive a transfer from the government each period and their choice is limited to the allocation of expenditure between tradable and nontradable goods. The government then chooses the aggregate level of external debt taking into account the pecuniary externality created by the combination of downward nominal wage rigidity and a currency peg.

We close this section by pointing out that the allocation induced by the Ramsey optimal capital control policy can also be supported through consumption taxes. Specifically, assume that instead of taxing external debt, the government taxes total consumption expenditures,

[3]An alternative proof that (17) must be satisfied in the less constrained Ramsey problem is as follows. Suppose, contrary to what we wish to show, that in the Ramsey allocation $h_t < \bar{h}$ and $w_t > \gamma w_{t-1}$ at some date t. Then, by (23) and (24), it must be the case that $\lambda_t^h = \lambda_t^w = 0$. But then, by (20) and by the facts that $P_2(c_t^T, h_t) < 0$ and $F''(h_t) < 0$, we have that $\lambda_t^p > 0$. This implication contradicts condition (22), which indicates that $\lambda_t^p = -\beta\gamma E_t \lambda_{t+1}^w \leq 0$ (recall that $\lambda_t^w \geq 0$).

[4]Strictly speaking, the marginal utility of consumption of tradables is decreasing in total consumption only if the intertemporal elasticity of substitution is smaller than the intratemporal elasticity of substitution.

$c_t^T + p_t c_t^N$ at the rate τ_{t-1}^c, so that the after-tax cost of consumption in period t is $(c_t^T + p_t c_t^N)(1+\tau_{t-1}^c)$. The consumption tax rate is determined one period in advance. That is, in period t the government announces the tax rate on consumption expenditures in period $t+1$. One can show that the Ramsey allocation can be supported by a consumption-tax-rate process of the form $1+\tau_t^c = (1-\tau_t^d)(1+\tau_{t-1}^c)$, for any initial condition $\tau_{-1}^c > -1$, where τ_t^d represents the Ramsey optimal tax rate on external debt given in equation (26).

4 An Analytical Example: Interest Rate Shocks and the Optimality of Prudential Capital Controls

In this section, we present an analytical example showing the prudential nature of optimal capital controls. Specifically, in the economy analyzed here, the Ramsey policy completely smoothes consumption in response to a temporary decline in the interest rate in order to attenuate the impact of this shock on unemployment once the interest rate goes back up to its long-run level.

Consider an economy like the one studied thus far in which the government pegs the nominal exchange rate. Assume that preferences are given by $U(c_t) = \ln(c_t)$ and $A(c_t^T, c_t^N) = c_t^T c_t^N$. The technology for producing nontradable goods is $F(h_t) = h_t^\alpha$, with $\alpha \in (0,1)$. Assume that the economy starts period zero with no outstanding debt, $d_0 = 0$. The endowment of tradables, y^T, is constant over time. The real wage in period -1 equals αy^T. The economy is subject to a temporary interest rate decline in period zero. Specifically, $r_t = r$ for all $t \neq 0$, and $r_0 = \underline{r} < r$. This interest-rate shock is assumed to be unanticipated. Finally, assume that $\beta(1+r) = 1$, that $\gamma = 1$, and that $\bar{h} = 1$. The economy is assumed to have been at a full-employment equilibrium in periods $t < 0$, with $d_t = 0$, $c_t^T = y^T$, $c_t^N = \bar{h}^\alpha$, and $h_t = \bar{h}$.

The following proposition presents the aggregate dynamics of this economy under free capital mobility, under optimal capital controls, and under the first-best equilibrium.

Proposition 1 (The Prudential Nature of Optimal Capital Controls) *In the economy described above, aggregate dynamics under free capital mobility are given by*

$$c_0^T = y^T \left[\frac{1}{1+\underline{r}} + \frac{r}{1+r}\right] > y^T$$

$$c_t^T = y^T \left[\frac{1}{1+r} + \frac{r}{1+r}\frac{1+\underline{r}}{1+r}\right] < y^T; \quad t \geq 1$$

$$d_t = y^T \left[1 - \frac{1+\underline{r}}{1+r}\right] > 0; \quad t \geq 1$$

$$h_0 = 1,$$

$$h_t = \frac{1+\underline{r}}{1+r} < 1; \quad t \geq 1.$$

And the Ramsey optimal allocation when the planner uses capital controls as the policy instrument is given by

$$c_t^T = y^T; \quad t \geq 0$$

$$h_t = 1; \quad t \geq 0$$

$$d_t = 0; \quad t \geq 0$$

and

$$\tau_t^d = \begin{cases} 1 - \frac{1+\underline{r}}{1+r} & \textit{for } t = 0 \\ 0 & \textit{for } t \geq 1 \end{cases}$$

The first-best allocation is given by

$$c_0^T = y^T \left[\frac{1}{1+\underline{r}} + \frac{r}{1+r} \right] > y^T$$

$$c_t^T = y^T \left[\frac{1}{1+r} + \frac{r}{1+r} \frac{1+\underline{r}}{1+r} \right] < y^T; \quad t \geq 1$$

$$d_t = y^T \left[1 - \frac{1+\underline{r}}{1+r} \right] > 0; \quad t \geq 1$$

$$h_t = 1; \quad t \geq 0.$$

Proof: See appendix A.

Under free capital mobility, agents borrow internationally to take advantage of the temporarily lower interest rate. The resulting capital inflow drives up consumption of tradables and real wages. When the interest rate returns to its long-run level, aggregate demand falls and unemployment emerges as real wages are too high to be consistent with full employment. As stressed throughout the paper, the rigidity of real wages is caused by the combination of downward nominal wage rigidity and a fixed exchange rate. The optimal capital control policy taxes capital inflows in period 0 to curb the boom in aggregate demand and in this way also limit the appreciation of real wages in period 0. Indeed, the Ramsey planner finds it optimal to fully undue the temporary decline in the world interest rate. The effective interest rate faced by domestic households is given by r even in period 0. In this way, consumption is fully smoothed over time and as a result the labor market is unaffected by the temporary decline in interest rates.

This example clearly illustrates the tradeoff between the efficient intertemporal allocation of expenditures in tradable goods and full employment. Under free capital mobility, the intertemporal allocation of tradable consumption is the one associated with the first-best equilibrium. However, output in the nontraded sector is inefficiently low in all periods following the initial one, as labor resources remain unemployed. By contrast, under optimal capital controls, the intertemporal allocation of tradable expenditure is inefficient. For it is not optimal to smooth consumption in response to changes in the interest rate. At the same time, the labor market operates under full employment at all times, which is consistent with the first-best allocation.

5 Dynamics Under Optimal Capital Controls

We wish to characterize aggregate dynamics under optimal capital controls. Of particular interest is to compare the model's predictions with and without capital controls. Given the complexity of the model, this question must be addressed using numerical methods. Specifically, using a calibrated version of the model, we compare aggregate dynamics and welfare associated with free capital mobility and with the optimal capital control policy.

We assume a CRRA form for the period utility function, a CES form for the aggregator function, and an isoelastic form for the production function of nontradables:

$$U(c) = \frac{c^{1-\sigma} - 1}{1 - \sigma},$$

$$A(c^T, c^N) = \left[a(c^T)^{1-\frac{1}{\xi}} + (1-a)(c^N)^{1-\frac{1}{\xi}} \right]^{\frac{\xi}{\xi-1}},$$

and

$$F(h) = h^{\alpha}.$$

We calibrate the model at a quarterly frequency. All parameter values are taken from Schmitt-Grohé and Uribe (2011a) and are shown in table 1. A novel and central parameter in our model is γ, governing the degree of downward nominal wage rigidity. In Schmitt-Grohé and Uribe (2011a), we present empirical evidence suggesting that nominal wages are downwardly rigid, and that our calibration of 0.99 for γ is conservative, in the sense that the empirical evidence points to values of γ greater than 0.99. For instance, there we document that in the thirteen-quarter period 2008:Q1 to 2011:Q2 unemployment rose in eleven peripheral European countries that are either on the Euro or pegging to the Euro.[5] According to our model, during this period the lower bound on nominal wages should have

[5] The countries considered are Bulgaria, Cyprus, Estonia, Greece, Ireland, Lithuania, Latvia, Portugal, Spain, Slovenia, and Slovakia.

Table 1: Calibration

Parameter	Value	Description
γ	0.99	Degree of downward nominal wage rigidity (Schmitt-Grohé and Uribe, 2011a)
σ	5	Inverse of intertemporal elasticity of consumption (Ostry and Reinhart, 1992)
y^T	1	Steady-state tradable output
$\bar{h}$	1	Labor endowment
a	0.26	Share of tradables (Schmitt-Grohé and Uribe, 2011a)
ξ	0.44	Intratemporal Elasticity of Substitution (González Rozada et al., 2004)
α	0.75	Labor share in nontraded sector (Uribe, 1997)
β	0.9375	Quarterly subjective discount factor (Schmitt-Grohé and Uribe, 2011a)

Note. See Schmitt-Grohé and Uribe (2011a) for details.

been binding. This means that nominal wages should have grown at the gross rate γ. We report that during this period the average growth rate of nominal hourly wages across countries was 2.3 percent per year. This implies an average (quarterly) value of γ of 1.0057. We set γ to 0.99 to accommodate for two features of the data that our model abstracts from, namely, foreign inflation and productivity growth. Specifically, our calibration of γ allows for up to 6 percent per year, i.e., (1.0057-0.99)$\times$4, of foreign inflation and productivity growth. Over the period in question, the average rate of CPI inflation in Germany was 1.12 percent per year. This means that our calibration allows for up to 4.8 percent of productivity growth per year, which seems on the high side. It is in this precise sense that we maintain that our calibrated value of γ allows for more downward flexibility in wages than was observed in the periphery of Europe since the onset of the great recession.

We assume that tradable output and the country interest rate, denoted r_t, follow a bivariate, first-order, autoregressive process of the form

$$\begin{bmatrix} \ln y_t^T \\ \ln \frac{1+r_t}{1+r} \end{bmatrix} = A \begin{bmatrix} \ln y_{t-1}^T \\ \ln \frac{1+r_{t-1}}{1+r} \end{bmatrix} + \nu_t, \tag{28}$$

where ν_t is a white noise of order 2 by 1 distributed $N(\emptyset, \Sigma_\nu)$. The parameter r denotes the deterministic steady-state value of r_t. The country interest rate r_t represents the rate at which the country can borrow in international markets. In our baseline calibration, we adopt the estimate of this process reported in Schmitt-Grohé and Uribe (2011a). There, we estimate the system (28) using Argentine data over the period 1983:Q1 to 2001:Q4. Our

OLS estimates of the matrices A and Σ_ν and of the scalar r are

$$A = \begin{bmatrix} 0.79 & -1.36 \\ -0.01 & 0.86 \end{bmatrix}; \qquad \Sigma_\nu = \begin{bmatrix} 0.00123 & -0.00008 \\ -0.00008 & 0.00004 \end{bmatrix}; \qquad r = 0.0316.$$

(Later in section 10 we estimate this process using data from Greece and Spain.) We discretize the AR(1) process given in equation (28) using 21 equally spaced points for $\ln y_t^T$ and 11 equally spaced points for $\ln(1 + r_t)/(1 + r)$. For details, see Schmitt-Grohé and Uribe (2011a).

We numerically approximate the equilibrium dynamics under the optimal capital control policy by applying the method of value function iteration over a discretized state space. The state of the economy in period $t \geq 0$ consists of the exogenous variables y_t^T and r_t, the endogenous state d_t, and the endogenous predetermined variable w_{t-1}. The welfare of the representative household under the optimal capital control policy can be approximated by solving the functional equation (27) subject to (8)-(12).

Approximating the dynamics of the model economy under free capital mobility is computationally more demanding than doing so under optimal capital control policy. The reason is that, because of the distortions introduced by the combination of downward nominal wage rigidity and a currency peg, aggregate dynamics can no longer be cast in terms of a Bellman equation without introducing additional state variables. Therefore to approximate the solution, we continue to discretize the state space $(y_t^T, r_t, d_t, w_{t-1})$, but perform policy-function iteration rather than value-function iteration. For details see Schmitt-Grohé and Uribe (2011a).

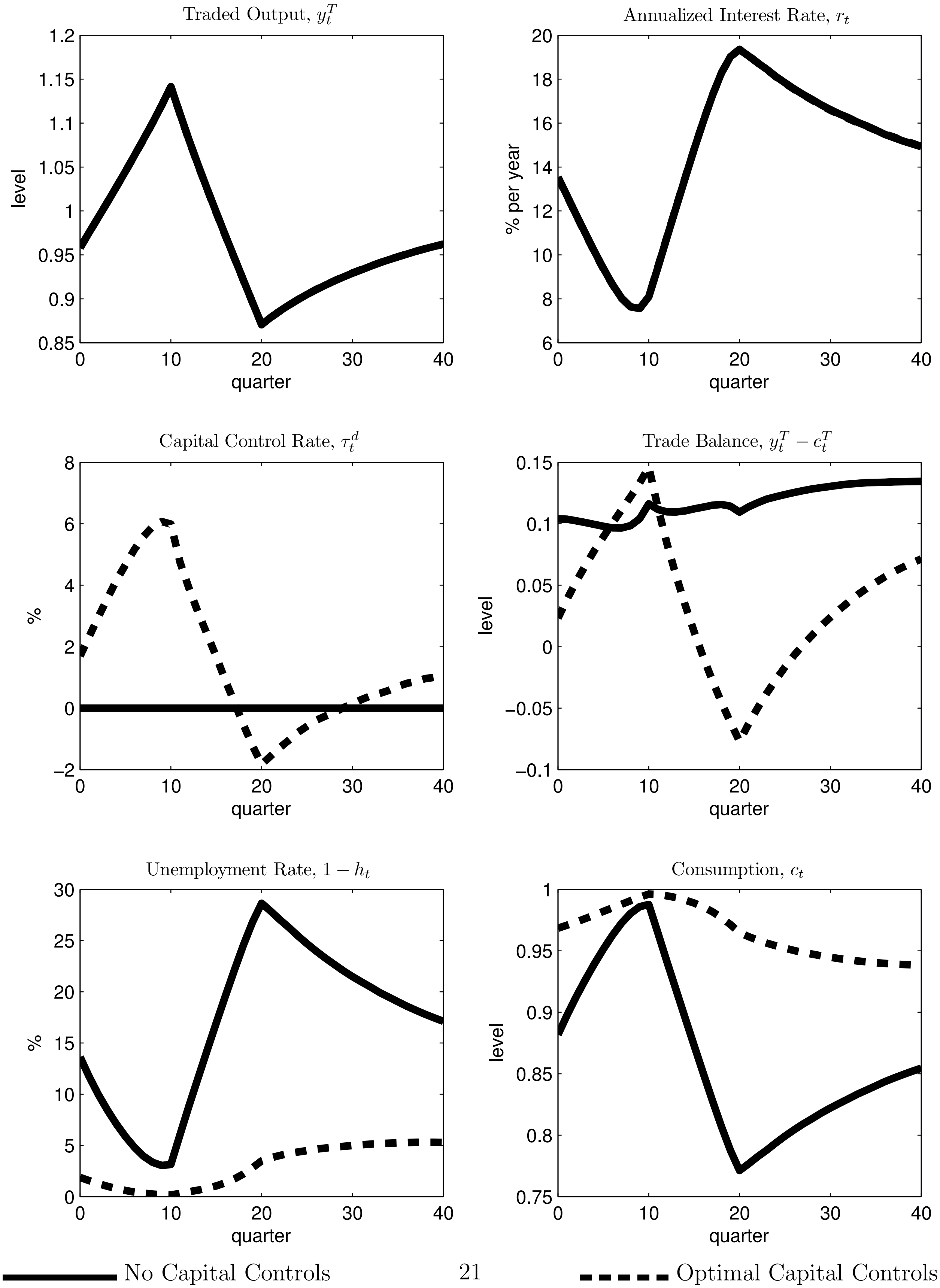
In approximating the aggregate dynamics of the economies with and without capital controls, we discretize the endogenous dimensions of the state space using 501 equally spaced points for the level of d_t and 500 equally spaced points for the logarithm of w_{t-1}.

5.1 Optimal Capital Controls During a Boom-Bust Episode

To illustrate the prudential nature of optimal capital controls in an economy undergoing a currency peg, we simulate a boom-bust episode. We define a boom-bust episode as a situation in which tradable output, y_t^T, is at or below trend in period 0, at least one standard deviation above trend in period 10, and at least one standard deviation below trend in period 20. To this end, we simulate the model economy for 20 million periods and select all subperiods that satisfy our definition of a boom-bust episode. We then average across these episodes.

Figure 3 depicts the model's predictions during a boom-bust cycle. Solid lines correspond to the economy with free capital mobility and broken lines to the economy with optimal

Figure 3: Prudential Policy For Peggers: Boom-Bust Dynamics With and Without Capital Controls



capital controls. The two top panels of the figure display the dynamics of the two exogenous driving forces, tradable output and the country interest rate. By construction, y_t^T and r_t are unaffected by capital controls. The middle left panel of the figure shows that capital controls increase significantly during the expansionary phase of the cycle, from about 2 percent at the beginning of the episode to almost 7 percent at the peak of the cycle. During the contractionary phase of the cycle, capital controls are drastically relaxed. Indeed at the bottom of the crisis, capital inflows are actually subsidized at a rate of about 2 percent.

The sharp increase in capital controls during the expansionary phase of the cycle puts sand in the wheels of capital inflows, thereby restraining the boom in consumption (see the bottom right panel of figure 3). Under free capital mobility, during the boom, consumption increases significantly more than under the optimal capital control policy. In the contractionary phase, the fiscal authority incentivates spending by subsidizing capital inflows. As a result consumption falls by much less in the regulated economy than it does in the unregulated one. During the recession, the optimal capital control policy, far from calling for austerity in the form of trade surpluses, facilitates large trade balance deficits as shown in the middle right panel of figure 3. In this way, the capital control policy is able to stabilize the absorption of tradable goods (not shown in figure 3) over the cycle. It follows that the Ramsey-optimal capital control policy does not belong to the family of beggar-thy-neighbor policies, for it does not seek to foster external demand during crises.

Because unemployment depends directly upon variations in the level of tradable absorption through the latter's role as a shifter of the demand schedule for nontradables, and because optimal capital controls stabilize the absorption of tradables, unemployment is also stable over the boom-bust cycle. Specifically, as can be seen from the bottom left panel of figure 3, in the absence of capital controls, unemployment increases sharply by over 20 percentage points during the recession. By contrast, under optimal capital controls the rate of unemployment rises relatively modestly by about 3 percentage points. It follows that the Ramsey planner's tradeoff between distorting the intertemporal allocation of tradable consumption and reducing unemployment is overwhelmingly resolved in favor of the latter.

Summarizing, the optimal capital control policy is prudential. It calls for restricting capital inflows during booms and encouraging them during contractions. In this way, the optimal capital control policy strengthens the role of the current account as a vehicle to stabilize domestic absorption over the business cycle. Optimal government intervention results in trade deficits during recessions and trade surpluses during booms of a much larger scale than would occur under free capital mobility.

Our model of involuntary underemployment due to downward nominal wage rigidity and a currency peg creates an endogenous connection between the cyclical and secular components

Table 2: Optimal Capital Controls: Level, Volatility and Welfare Effects

Variable	Symbol	Mean: Optimal Capital Controls	Mean: No Capital Controls	Standard Deviation: Optimal Capital Controls	Standard Deviation: No Capital Controls
Capital Control Rate	τ_t^d	2.4	0	5.2	0
Unemployment Rate	$\bar{h} - h_t$	3.1	13.5	7.6	11.7
Consumption	c_t	0.97	0.89	0.08	0.10
Trade Balance	$y_t^T - c_t^T$	0.05	0.11	0.12	0.07
Real Wage	W_t/E_t	2.1	2.3	0.6	0.7
Traded Output	y_t^T	1.0	1.0	0.1	0.1
Interest Rate	r_t	13.2	13.2	7.4	7.4
External Debt	d_t	0.9	3.4	2.3	0.7
Debt-to-Output Ratio	$d_t/4/(y^T + p_t c_t^N)$	11.2	26.0	22.1	12.6
Welfare Cost of Free Capital Mobility					
	λ_1	2.2 percent of consumption			
	λ_2	2.9 percent of consumption			

Note. τ_t^d, $\bar{h} - h_t$, and $d_t/4/(y_t^T + p_t c_t^N)$ are expressed in percent, r_t is expressed in percent per year, and c_t, $y_t^T - c_t^T$, W_t/E_t, y_t^T, and d_t are expressed in levels. The welfare costs of free capital mobility, λ_1 and λ_2, are calculated using the formulas given in equations (29) and (30), respectively.

of macroeconomic aggregates. Specifically, in our model the larger the amplitude of the cycle, the larger the average rate of unemployment. The optimal capital control policy succeeds in reducing average unemployment by smoothing aggregate absorption over time, thereby greatly elevating the average abundance of goods.

6 Level and Volatility Effects of Optimal Capital Controls

Table 2 displays unconditional first and second moments of macroeconomic indicators of interest for the economies with optimal capital controls and free capital mobility.

On average, the Ramsey planner imposes a positive tax on external debt of 2.4 percent. This figure implies large average levels of capital controls, for the effective interest rate faced by domestic debtors, given by $(1 + r_t)/(1 - \tau_t^d)$, increases from 13.2 percent per year under free capital mobility to 24.8 percent per year under optimal capital controls. The main reason why the Ramsey planner finds it optimal to impose capital controls on average is to lower the average level of external debt holdings. We postpone an explanation of why this is optimal until section 7.

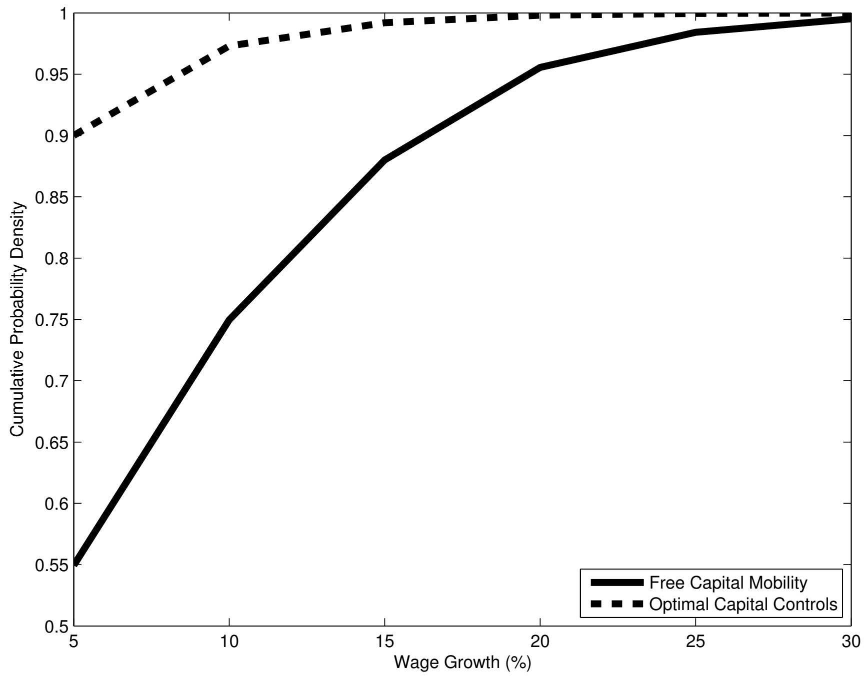
Table 2 also shows that the tax on debt is highly volatile, with a standard deviation of 5.2 percentage points per quarter. The main payoff of imposing highly cyclical capital controls is an enormous reduction in the average rate of unemployment from 13 percent under free capital mobility to 3 percent under the optimal capital control policy. This reduction in unemployment is welfare increasing because it raises the average level of production, and hence also absorption, of nontradables, which provide utility to domestic households.

The reduction in unemployment is mediated by a significant reduction in the volatility of the growth rate of tradable absorption. The standard deviation of the growth rate of tradable consumption, c_t^T/c_{t-1}^T, not shown in the table, falls from 5.3 percent under free capital mobility to 2.9 percent under optimal capital controls. The connection between the volatility of tradable consumption growth and unemployment follows from the fact that consumption of tradables plays the role of a shifter of the demand for nontradables. In turn, the Ramsey planner succeeds in curbing the variance of tradable expenditure growth by raising the cost of external borrowing during booms and lowering it during recessions. The correlation between traded output y_t^T and the capital control rate τ_t^d is 0.54 and the correlation between the interest rate r_t and τ_t^d is -0.58. Furthermore, the Ramsey planner engineers an effective interest rate that is positively correlated with traded output in spite of the fact that the interest rate itself is highly negatively correlated with the latter.

Table 2 shows that the first and second moments of the real (and nominal) wage rates are not significantly affected by the presence of capital controls. This prediction of the model might appear as surprising because downward wage rigidity is the sole friction in the present model, and because unemployment behaves markedly differently across capital control regimes. A reason why the unconditional moments of real wages are so similar in the two regimes is that the lower bound on wages is binding most of the time in both economies (85 percent of the time under free capital mobility and 65 percent of the time under optimal capital controls), and, when this happens, the wage rate falls at the common gross rate γ. A reason why the first and second moments of unemployment are so different across regimes in spite of the similarity in the corresponding moments of real wages is that when the wage constraint is binding the magnitude of the unemployment rate depends on the strength of the domestic absorption of tradables, which is significantly different across regimes.

An important distinction in wage dynamics across capital control regimes that is not captured by the unconditional moments shown in table 2 is the behavior of wages during booms. During economic expansions, the Ramsey fiscal authority, through capital controls, limits the appreciation of real wages. In this way, it also reduces the need for large decreases in the real wage once the boom is over. To visualize the role of optimal capital controls in limiting wage increases during booms, figure 4 displays the cumulative probability distribu-

Figure 4: Cumulative Probability Distribution of Positive Wage Changes



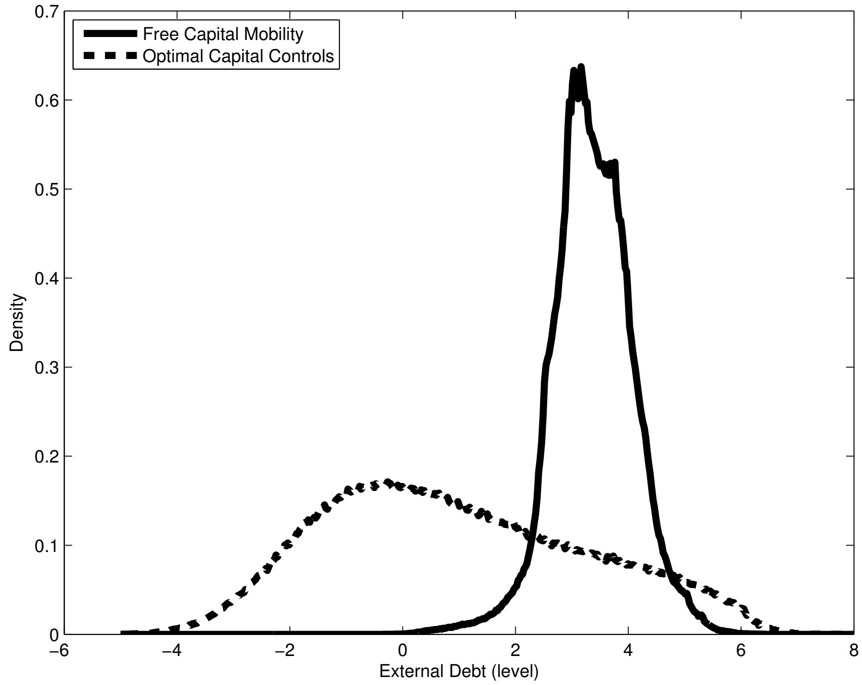
tion of positive wage changes under free capital mobility and under optimal capital controls. Under optimal capital controls the vast majority of wage increases are small. Specifically, 90 percent of wage increases are less than 5 percent in magnitude. By contrast, only about half of all wage increases that occur under free capital mobility are smaller than 5 percent. This difference underlines the prudential nature of optimal capital controls.

7 Peg-Induced Overborrowing

Table 2 shows that the average level of external debt in the economy with free capital mobility is more than three times higher than it is in the economy with optimal capital controls. This prediction of the model is also evident from figure 5, which shows the unconditional distribution of external debt under free capital mobility (solid line) and under optimal capital controls (dashed line). The Ramsey planner induces a lower average level of external debt by taxing borrowing at a positive rate. Recall that the average tax rate on debt is 2.4 percent per quarter. It follows that pegging economies with free capital mobility accumulate inefficiently large amounts of external debt. In other words currency pegs in combination with free capital mobility lead to overborrowing.

The reason why the average level of external debt is lower under optimal capital controls than under free capital mobility is that the Ramsey planner finds it optimal to induce an

Figure 5: The Distribution of External Debt



external debt position that is significantly more volatile than the one associated with free capital mobility. As shown in table 2, the standard deviation of external debt is 2.3 under optimal capital controls, but only 0.7 under free capital mobility. Similarly, figure 5 shows that the distribution of external debt is significantly more dispersed under optimal capital controls than under free capital mobility. A more volatile process for external debt requires centering the debt distribution further away from the natural debt limit, for precautionary reasons. In turn, the reason why the Ramsey planner finds wide swings in the external debt position desirable is that such variations allow him to insulate the domestic absorption of tradable goods from exogenous disturbances buffeting the economy. Put differently, in the Ramsey economy, external debt plays the role of shock absorber to a much larger extent that it does in the economy with free capital mobility.

Finally, we wish to stress that the purpose of optimal capital controls is not to close the current account. On the contrary, under optimal capital controls, the economy makes more heavy use of the current account to smooth consumption than it does under free capital mobility. To see this, note that the current account is given by the change in net external debt, and that, as is apparent from figure 5, the net external debt has a much more dispersed distribution under optimal capital controls than under free capital mobility.

8 Welfare Costs of Free Capital Mobility for Peggers

We have established that in the present economy, free capital mobility entails excessive external debt and unemployment. Both of these factors tend to depress consumption and therefore reduce welfare. In this section, we quantify the welfare losses associated with free capital mobility in economies subject to a currency peg.

The welfare cost of free capital mobility conditional on state $s_t \equiv \{y_t^T, r_t, d_t, w_{t-1}\}$, denoted $\lambda(s_t)$, is defined as the permanent percent increase in the lifetime consumption stream required by an individual living in the economy with free capital mobility in state s_t to be as well off as an individual living in the economy with optimal capital controls in state s_t. Formally, $\lambda(s_t)$ is implicitly given by

$$\mathbb{E}\left\{\sum_{j=0}^{\infty}\beta^j U(c_{t+j}^{FCM}(1+\lambda(s_t)))\middle| s_t\right\} = \mathbb{E}\left\{\sum_{j=0}^{\infty}\beta^j U(c_{t+j}^{OCC})\middle| s_t\right\},$$

where c_t^{FCM} and c_t^{OCC} denote, respectively, consumption in the economy with free capital mobility and consumption in the economy with optimal capital controls in period t. Because the state vector s_t is stochastic, the conditional welfare cost measure, $\lambda(s_t)$, is itself stochastic. We wish to compute the unconditional mean of $\lambda(s_t)$. This requires knowledge of the unconditional probability distribution of s_t. However, in our economy, the distribution of the endogenous state vector depends on the capital control regime (see 5 for the case of debt). We therefore compute two mean welfare cost measures. In one we assume that the distribution of the state vector is that associated with the free capital mobility regime and in the other we assume that the distribution of the state vector is that of the optimal capital control regime. Specifically, let λ_1 denote the unconditional mean of $\lambda(s_t)$ when the distribution of s_t is the one induced by free capital mobility and let λ_2 denote the unconditional mean of $\lambda(s_t)$ when the distribution of s_t is the one induced by optimal capital controls. Formally, let $\pi^{FCM}(s_t)$ denote the unconditional probability of s_t under free capital mobility and $\pi^{OCC}(s_t)$ the unconditional probability of s_t under the optimal capital control policy. Then λ_1 and λ_2 are, respectively, given by

$$\lambda_1 = \sum_{s_t}\pi^{FCM}(s_t)\lambda(s_t) \tag{29}$$

and

$$\lambda_2 = \sum_{s_t}\pi^{OCC}(s_t)\lambda(s_t). \tag{30}$$

Table 2 shows that the average welfare costs of free capital mobility for a pegging economy are large. The representative household living in the economy with free capital mobility requires on average an increase of 2.2 percent in consumption every period to be indifferent between living under free capital mobility and living under optimal capital controls. At the same time, if we average the welfare costs of free capital mobility using the unconditional distribution of the state under optimal capital controls, then the mean welfare cost rises to 2.9 percent of consumption. The difference between λ_1 and λ_2 is explained by the fact that under free capital mobility the economy is on average more indebted. The transition from a free capital mobility regime to the optimal capital control regime therefore requires a significant amount of deleveraging if the distribution of s_t is the one induced by free capital mobility. In turn, deleveraging forces households to temporarily cut consumption of traded goods making it less enticing to switch from free capital mobility to optimal capital controls.

We interpret our results as suggesting that the present model speaks with a strong voice against allowing capital to flow freely across borders in economies with fixed exchange rates and downwardly rigid wages. However, optimal capital control policies are significantly less effective than first best policies in neutralizing the deleterious effects of downward wage rigidity. In Schmitt-Grohé and Uribe (2011a) we show that first-best policies, such as optimal devaluations of the nominal exchange rate, optimal labor subsidies, or optimal production subsidies in the nontraded sector, increase welfare by about 12 percent of the consumption stream. It follows that the second-best policy considered in this paper achieves at most a fourth of the welfare gains that are attainable under first best policies.

9 Financial Frictions

Thus far, we have considered a model in which the only departure from the neoclassical paradigm is downward nominal wage rigidity. A recent literature has emphasized the role of financial frictions for understanding overborrowing and fire sales of assets during crises (e.g., Lorenzoni, 2008; Korinek, 2010; Jeanne and Korinek, 2012; Benigno et al., 2011; Bianchi, 2011; and Bianchi and Mendoza, 2012). A central theme of this literature is that collateral constraints in which the household's ability to borrow depends upon a price (be it a product price, a factor price, or an asset price) generate a pecuniary externality and open the door for prudential macroeconomic policy. A general result of this literature is that, although capital controls go a long way toward containing the severity of sudden stops, their welfare benefits are quantitatively small, typically around one tenth of one percent of permanent consumption. In this section, we study how the welfare costs of free capital mobility stemming from the externality identified in this paper change when financial frictions are introduced.

We consider a financial friction that has been extensively studied in the related open economy literature. It takes the form of an upper bound on the external-debt-to-output ratio. Formally, we augment the model by introducing the collateral constraint

$$d_{t+1} \leq \kappa(y_t^T + p_t y_t^N), \tag{31}$$

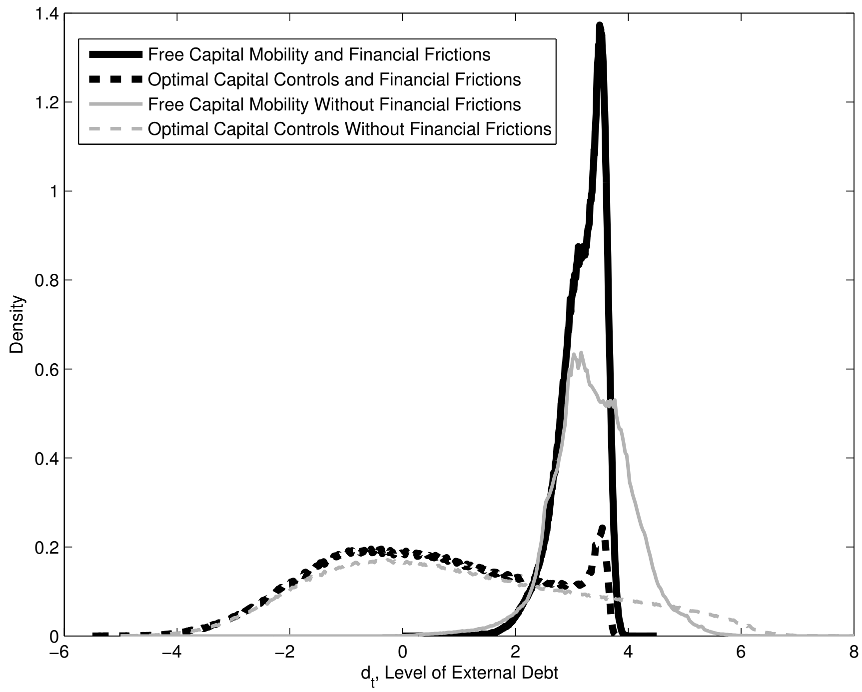
where $\kappa > 0$ is a parameter and $y_t^N \equiv F(h_t)$ denotes aggregate per capita output of nontradables. The resulting model is identical to the one considered in Ottonello (2012) who merges our wage-rigidity framework with a financial constraint of the type introduced in Bianchi (2011). Ottonello shows that this model features a policy tradeoff whereby a devaluation can reduce involuntary unemployment by lowering the real wage but at the same time may tighten the collateral constraint by reducing the value of nontradable output in terms of tradable goods. Our focus here is not on exchange-rate policy—we limit attention to an exchange-rate peg—but rather on the effectiveness of capital controls to address the two externalities present in the model, namely the one created by the combination of a currency peg and downward wage rigidity and the one stemming from the collateral constraint.

We set $\kappa = 0.64 \times 4$. This value corresponds to the maximum debt-to-annual-GDP ratio of 64 percent reported by Lane and Milesi-Ferretti (2009) for Argentina over the period 1970-2007. All other parameters are set as shown in table 1.

Figure 6 displays with a solid black line the unconditional density function of external debt, d_t, under free capital mobility and with a broken black line the density of external debt under optimal capital controls. To facilitate comparison, the figure reproduces with solid and broken gray lines, respectively, the distributions of debt under free capital mobility and optimal capital controls associated with the economy without financial frictions (these lines are identical to those shown in figure 5). The main result conveyed by the figure is that as in the case of no financial frictions, peggers overborrow. The average debt-to-output ratio in the economy with financial frictions is 23.5 percent under free capital mobility and 5.5 percent under capital controls, compared to 26.0 and 11.2, respectively, in the economy without financial frictions. That is, the introduction of financial frictions increases the average level of overborrowing somewohat, from 14.8 to 18.0 percent of GDP.

The welfare costs of free capital mobility are also little changed by the introduction of financial frictions. In the economy with financial frictions households living under free capital mobility require an increase in their consumption stream of 2.3 percent to be as well off as households living in the economy with optimal capital controls, compared to 2.2 percent in the economy without financial frictions. The difference in the welfare cost of free capital mobility in the economies with and without financial frictions is one tenth of one percent of consumption, which is a number similar in magnitude to the cost of free capital mobility

Figure 6: Overborrowing In The Economy With Financial Frictions



reported in models with flexible wages (e.g., Bianchi, 2011). It follows that in our model, like in the models cited at the beginning of this section, the welfare costs of free capital mobility attributable to collateral constraints alone are small. By contrast, the welfare costs of free capital mobility attributable to the externality identified in this paper, namely, the one created by the combination of downward nominal wage rigidity and a fixed exchange rate, are sizable.

On issue with collateral constraints of the type considered here is that from the planner's perspective, they might display a perverse behavior. Specifically, it may be the case that the collateral constraint may be satisfied for large values of d_{t+1} but violated for smaller values. This is because, for a given state of the economy, a higher value of d_{t+1} is associated with higher consumption of tradables and, in equilibrium, with a higher relative price of nontradables. In turn, the higher price of nontradables raises the value of nontradable output in terms of tradables thereby increasing the value of collateral. If this effect is strong enough, then the increase in d_{t+1} may indeed relax the collateral constraint. This situation occurs for a large number of states under the present calibration. This problem is not specific to the present theoretical framework, but is present in all models with collateral constraints of the form given in equation (31). At the individual level, the collateral constraint is always well behaved, since households take the value of collateral as independent of their net foreign asset position.

We close this section by considering a case in which the collateral constraint is significantly more stringent. Specifically, we now set κ at 1.28 (half the value used above), which implies that the debt-to-annual-output ratio cannot exceed 32 percent. All other parameters are as before. We find that the welfare gain from optimal capital controls is 2.7 percent, a value not significantly different from the one obtained for $\kappa = 2.56$. We conclude that the welfare gains of optimal capital controls stem primarily from the externality caused by the combination of downward nominal wage rigidity and a fixed exchange rate regime and not from the one originated in the financial friction.

10 Greece and Spain

In this section we investigate the sensitivity of our quantitative results to changes in the exogenous driving process. Specifically, we estimate the law of motion of traded output and the country interest rate using quarterly data from two peripheral European countries, Greece and Spain over the period 1980-2011. Appendix B describes the data sources. The estimates of A, Σ_ν, and r defining the exogenous bivariate first-order autoregressive processes given in equation (28) are

$$A = \begin{bmatrix} 0.88 & -0.42 \\ -0.05 & 0.59 \end{bmatrix}; \quad \Sigma_\nu = \begin{bmatrix} 0.000536 & -0.000010 \\ -0.000010 & 0.000060 \end{bmatrix}; \quad r = 0.011.$$

for Greece and

$$A = \begin{bmatrix} 0.95 & 0.04 \\ 0.01 & 0.78 \end{bmatrix}; \quad \Sigma_\nu = \begin{bmatrix} 0.000134 & -0.000000 \\ -0.000000 & 0.000046 \end{bmatrix}; \quad r = 0.0123.$$

for Spain. Table 3 displays some features of the process $[y_t^T \; r_t]'$ implied by our estimates. Both Greece and Spain face lower interest rates than Argentina. The average value of r_t is about 5 percent for Greece and Spain and over 13 percent for Argentina. In addition, the two European economies face smaller external shocks. The estimated volatilities of tradable output and the interest rate in these two countries are significantly lower than their Argentine counterparts.

In solving the model using the Greek and Spanish driving forces, we keep all other structural parameters of the model constant (see table 1). We do this because we wish to isolate the effect of changes in the level of uncertainty. A potential problem with this strategy is that the implied stochastic steady state may not match salient features of the

Table 3: Model Implications Using Data From Greece and Spain

Statistic	Argentina	Greece	Spain
Interest Rate (% yr.)			
Mean	13.2	4.5	5.1
Standard Deviation	7.4	5.2	4.7
Traded Output, y_t^T (% dev. from trend)			
Standard Deviation	12.3	6.5	3.6
Corr(y_t^T, r_t)	-0.86	-0.62	0.13
Capital Control Rate, τ_t^d (% qtr.)			
Mean	2.4	3.3	3.4
corr(τ_t^d, y_t^T)	0.54	0.49	0.18
corr($\tau_t^d r_t$)	-0.58	-0.49	-0.56
Mean Unemployment (%)			
Free Capital Mobility	13.5	15.3	10.8
Optimal Capital Controls	3.1	3.8	2.2
Std. Dev. Consumption (%)			
Free Capital Mobility	12.5	16.1	12.1
Optimal Capital Controls	9.6	10.6	7.3
Debt-to-Output Ratio (%)			
Free Capital Mobility	26	113	162
Optimal Capital Controls	11	99	152
Welfare Cost of Free Capital Mobility (%)			
λ_1	2.2	2.4	1.8
λ_2	2.9	5.6	4.0

data. In particular, the mean debt-to-output ratio in Greece is 113 percent in the model and 98 percent in the data. For Spain the mean debt-to-output ratio is 162 percent in the model and 88 percent in the data. An alternative strategy, which we do not pursue here, would be to adjust the subjective discount factor β for each country.

The reduced level of external uncertainty lowers precautionary savings, and the lower average real interest rate makes external borrowing more attractive. As a result, as shown in table 3, the average long-run debt-to-output ratio implied by the model is much higher under the exogenous processes estimated on Greek and Spanish data than under the one estimated on Argentine data.

Lower uncertainty and higher levels of external debt have opposite effects on the welfare costs of capital mobility for peggers. On the one hand, all other things equal, less uncertainty makes free capital mobility less costly for peggers. On the other hand, as we show elsewhere (Schmitt-Grohé and Uribe, 2011b), a higher level of external debt increases the welfare cost of free capital mobility for peggers. In the case of Greece, for example, even though the level of uncertainty is lower than that of Argentina, the welfare cost of free capital mobility turns out to be higher than in Argentina. The reason is that the level of external debt induced by the exogenous driving process fit to Greek data is much higher than that induced by the process estimated with Argentine data.

The mean welfare costs of free capital mobility estimated for Spain are smaller than those estimated for Greece even though the implied external debt level for the former is much higher. We attribute this result to the fact that the Greek interest rate is strongly countercyclical whereas the Spanish interest rate is mildly procyclical. Using the terminology coined by Kaminsky et al. (2005), when it rains in Greece it pours, whereas it does not in Spain.

11 Conclusion

The first contribution of this paper is to identify a negative pecuniary externality afflicting economies with downward nominal wage rigidity and fixed exchange rates. In this type of economic environment, private absorption expands too much in response to favorable shocks, causing inefficiently large increases in real wages. No problems are manifested in this phase of the cycle. However, as the economy returns to its trend path, wages fail to fall quickly enough because they are downwardly rigid. In addition, the central bank, having its hands tied by the commitment to a fixed exchange rate, cannot deflate the real value of wages via a devaluation. In turn, high real wages and a contracting level of aggregate absorption cause involuntary unemployment. Individual agents are conscious of this mechanism, but are too small to internalize it. The government, on the other hand, does internalize the distortion and therefore has an incentive to intervene.

The second contribution of the present study is to analyze the ability of capital controls to ameliorate the distortions introduced by the peg-induced pecuniary externality. We characterize both analytically and numerically the Ramsey optimal capital control policy. We show that, although capital controls cannot bring about the first-best allocation, they can substantially ease the pains of pegs. Under plausible calibrations of our model, we find that the representative household living in the economy with free capital mobility requires a permanent increase in consumption between 2 and 5 percent to be unconditionally indifferent between continuing to live in that environment and migrating to one with optimally set capital controls.

The third contribution of the present investigation is to establish that the optimal capital control policy is prudential in nature. The benevolent government taxes capital inflows in good times and subsidizes external borrowing in bad times. As a result, the economy experiences trade surpluses during booms and deficits during recessions. The key role of capital controls is to insulate the domestic absorption of tradable goods from external shocks. In this way, the government avoids that external disturbances spill over into the nontraded sector where they would otherwise cause unemployment.

The fourth important finding of our inquiry is to establish that pegging economies are prone to overborrowing. In our calibrated model, the average debt-to-output ratio falls from 26 percent in the economy with free capital mobility to 11 percent in the economy with optimal capital controls. The regulated economy accumulates a war chest of assets (or a reduced level of debt) in order to be able to stabilize traded consumption when the economy is buffeted by negative external shocks.

In summary, the results of the present study strongly suggest that, when labor markets suffer from downward nominal wage rigidity, fixed exchange rate arrangements should not be coupled with free capital mobility. On the contrary, in such economies, capital controls can be a highly effective instrument for macroeconomic stabilization. More importantly, the predictions of our model suggest that governments of fixed-exchange-rate economies should concentrate effort not on crisis management, but rather on crisis prevention.

Appendix A: Proof of Proposition 1

Allocation Under Free Capital Mobility

From period 1 onward, the economy faces a constant interest rate forever. Therefore, all endogenous variables are constant over time. The resource constraints in periods 0 and 1 are then given by

$$c_0^T = y^T + d_1/(1+\underline{r})$$

and

$$c_1^T + d_1 = y^T + d_1/(1+r),$$

respectively. The second equation uses the fact that $d_2 = d_1$. The Euler equation in period 0 is

$$c_1^T = \beta(1+\underline{r})c_0^T.$$

This is a system of three equations in three unknowns, c_0^T, c_1^T, and d_1. Solving this system, we obtain

$$c_0^T = y^T \left[\frac{1}{1+\underline{r}} + \frac{r}{1+r}\right]$$

$$c_1^T = y^T \left[\frac{1}{1+r} + \frac{r}{1+r}\frac{1+\underline{r}}{1+r}\right],$$

and

$$d_1 = y^T \left[1 - \frac{1+\underline{r}}{1+r}\right].$$

Notice that if $\underline{r} = r$, then $c_1^T = y^T$ and $d_t = 0$. However, because $\underline{r} < r$, the economy experiences a boom in consumption in period 0. This boom is financed with external debt, $d_1 < 0$. From period 1 onward, traded consumption must fall because the economy needs to generate resources to service the external debt. The contraction in the absorption of tradables that takes place after period 0 causes unemployment in the nontraded sector. By equation (9), the real wage in period 0 is given by $\alpha c_0^T > w_{-1}$, indicating that capital inflows in period 0 cause an increase in the real wage. This elevation in real wages puts the economy in a vulnerable situation in period 1, when the interest rate goes back up to its permanent level r. The full-employment real wage in period 1 is αc_1^T, which is lower than $w_0(= \alpha c_1^T)$, because $c_1^T < c_0^T$. As a result, unemployment emerges and is equal to

$$1 - h_t = 1 - \frac{1+\underline{r}}{1+r} > 0,$$

for $t \geq 1$. Notice that the larger the decline in the interest rate in period 0, the larger is the unemployment rate in periods $t \geq 1$. This level of involuntary unemployment will persist forever, unless the policy authority does something to lower it.

Allocation Under Ramsey Optimal Capital Controls

In line with the approach adopted in section 3, the optimal capital control policy is the solution to a social planner problem in which the government picks the level of traded consumption in period 0, c_0^T, to maximize the welfare of the representative agent, taking into account the effect of movements in traded consumption on unemployment in the nontraded sector. Intuitively, the government wants to curb consumption of tradables in period 0 to dampen the rise in real wages. Then, capital controls are chosen so as to be consistent with the desired path of consumption.

The solution of the Ramsey problem is $c_t^T = y^T$ and $h_t = 1$ for all $t \geq 0$. The associated level of lifetime welfare is

$$\frac{1}{1-\beta} \ln y^T.$$

To see this, consider first a solution in which $c_0^T > y^T$. In this case, $d_1 > 0$ and therefore $c_t^T < y^T$ for all $t \geq 1$. In period 0, the full-employment wage is $\alpha c_0^T > w_{-1}$. It follows that $h_0 = 1$ and $w_0 = \alpha c_0^T$. In period 1, the full-employment wage rate is αc_1^T, which is less than w_0. As a result, we have that the lower bound on wages binds, $w_1 = w_0$. Equation (9) then implies that $h_t = c_t^T / c_0^T < 1$ for all $t \geq 1$. Lifetime utility is then given by

$$\frac{1-\beta(1+\alpha)}{1-\beta} \ln c_0^T + \frac{\beta(1+\alpha)}{1-\beta} \ln c_1^T.$$

Assuming that $\alpha > r$, we have that welfare at $c_0^T = y^T$ is larger than welfare at any $c_0^T > y^T$.

Now we wish to show that the proposed solution to the Ramsey problem dominates any other one in which $c_0^T < y^T$. If $c_0^T < y^T$, then $d_1 < 0$, and therefore $c_t^T > y^T$, for all $t \geq 1$. By combining the sequential budgets constraints in periods 0 and 1, given by $c_0^T = y^T + d_1/(1+\underline{r})$ and $c_1^T = y^T - \frac{r}{1+r} d_1$, we obtain that $c_1^T = \left[1 + r\frac{1+\underline{r}}{1+r}\right] y^T - \frac{r(1+\underline{r})}{(1+r)} c_0^T$. The full-employment real wage in period 0 is $\alpha c_0^T < w_{-1}$, which implies the existence of involuntary unemployment in period 0, $h_0 = c_0^T / y^T < 1$. By a similar logic, there is full employment starting in period 1, $h_t = 1$ for $t \geq 1$. Lifetime welfare is then given by

$$(1+\alpha) \ln c_0^T + \frac{\beta}{1-\beta} \ln \left[\left(1 + r\frac{1+\underline{r}}{1+r}\right) y^T - \frac{r(1+\underline{r})}{(1+r)} c_0^T \right] - \alpha \ln y^T$$

Notice that this expression reduces to the lifetime utility level under the proposed solution when $c_0^T = y^T$. Moreover, the derivative of the above expression with respect to c_0^T is positive for any $c_0^T \leq y^T$. This shows that the proposed solution dominates one in which $c_0^T < y^T$.

Finally, the capital control policy that supports the Ramsey equilibrium can be read off the household's Euler equation for consumption of tradables evaluated at $c_0^T = c_1^T = y^T$, which yields

$$\tau_0^d = 1 - \frac{1 + \underline{r}}{1 + r} > 0$$

for $t = 0$ and

$$\tau_t^d = 0$$

for $t \geq 1$.

Appendix B: Data Description

In this appendix, we report the estimate of the exogenous driving process $[y_t^T \; r_t]'$ for the cases of Greece and Spain. We also describe how the empirical measures of y_t^T and r_t were constructed.

Greece

The estimation uses quarterly data from 1981:Q1 to 2011:Q3. Greece did not produce sectoral GDP data between 1991 and 1999. For this reason, we proxy traded output by an index of industrial production. Specifically, we use the index of total manufacturing production 2005=100 from the OECD seasonally adjusted at the source. The original series begins in 1955:Q1 and ends in 2011:Q3. We removed a cubic trend from the natural logarithm of the index over the period 1955:Q1 to 2011:Q3. We use observations of the detrended series for the period 1981:Q1 to 2011:Q3 to make the range compatible with the one corresponding to the country real interest rate.

It is also difficult to obtain a consistent measure of the Greek real interest rate over the past three decades. The reason is twofold. First, JP Morgan does not produce the EMBI index for Greece. Second, we were unable to find an interest rate for a constant maturity instrument over the whole sample. In face of these data limitations, we proceed as follows. We measure the real interest rate in terms of tradables using the formula

$$1 + r_t = (1 + i_t)\mathbb{E}_t \left[\frac{E_t P_t^{T*}}{E_{t+1} P_{t+1}^{T*}} \right],$$

where r_t denotes the real country interest rate in terms of tradables, i_t denotes the nominal interest rate in terms of national currency, E_t denotes the nominal exchange rate defined as units of domestic currency per unit of ECU or Euro as applicable (Greece's legal tender changed to the Euro in 2001), P_t^{T*} denotes the foreign-currency price of tradables, and $\mathbb{E}_t$

denotes the expectations operator conditional on information available in period t. This formula assumes that the marginal rate of substitution is uncorrelated with the inverse of the domestic rate of inflation of tradable goods. The source for E_t is Eurostat (code `ert_h_eur_q`). We measure P_t^{T*} by the German consumer price index published by the OECD. We measure i_t as follows. For the period 1981:Q1 to 1992:Q3 it is the overnight interest rate published by the Bank of Greece. For the period 2001:Q1 to 2011:Q3 we proxy i_t by the interest rate on 10-year Greek treasury bonds published by Eurostat (code `irt_lt_mcby_q`). For the period 1992:Q4 to 2000:Q4, we measure i_t as the average of the above two interest rates. We proxy $\mathbb{E}_t\left[\frac{E_t P_t^{T*}}{E_{t+1} P_{t+1}^{T*}}\right]$ by the one-period ahead forecast of $\frac{E_t P_t^{T*}}{E_{t+1} P_{t+1}^{T*}}$ implied by an estimated AR(2) process for this variable. We discretize the driving process following the same procedure described in the body of the paper for the case of Argentina.

Spain

The estimation of the driving process uses quarterly data over the period 1980:Q3 to 2011:Q4. We proxy tradable output by the sum of sectoral GDP in agriculture, livestock breeding, forestry, fishing, and industry net of construction at constant prices of 1995. The source is INE (www.ine.es). The average share of tradables in GDP over the estimation sample is 26 percent. The logarithm of traded GDP is detrended by removing a cubic time trend. The procedure for constructing the Spanish real interest rate is similar to that employed for Greece, except that here we measure the nominal interest rate by the 10-year Spanish treasury bond published by Eurostat under the name EMU convergence criterion bond yields (code `irt_lt_mcby_q`).

References

Auernheimer, L. and R. García-Saltos, "International Debt and the Price of Domestic Assets," IMF Working Paper wp/00/177, October 2000.

Benigno, Gianluca, Huigang Chen, Christopher Otrok, Alessandro Rebucci, and Eric R. Young, "Revisiting Overborrowing and Its Policy Implications," in Cespedes, Luis Felipe, Roberto Chang, and Diego Saravia (Eds.), *Monetary Policy under Financial Turbulence,* Central Bank of Chile, 2011, 145-184.

Bianchi, Javier, "Overborrowing and Systemic Externalities in the Business Cycle," *American Economic Review 101,* December 2011, 3400-3426.

Bianchi, Javier and Enrique G. Mendoza, "Overborrowing, Financial Crises and Macroprudential Policy," manuscript, University of Wisconsin, July, 2012.

Costinot, Arnaud, Guido Lorenzoni, and Iván Werning, "A Theory of Capital Controls as Dynamic Terms-of-Trade Manipulation," NBER Working Paper 17680, December 2011.

Elsby, Michael, "Evaluating the Economic Significance of Downward Nominal Wage Rigidity," *Journal of Monetary Economics 56,* March 2009, 154-169.

Farhi, Emmanuel and Ivan Werning, "Dealing With the Trilemma: Optimal Capital Controls With Fixed Exchange Rates," manuscript, June 2012.

Galí, Jordi and Tommaso Monacelli, "Monetary Policy and Exchange Rate Volatility in a Small Open Economy," *Review of Economic Studies 72,* July 2005, 707-734.

González Rozada, Martín, Pablo Andrés Neumeyer, Alejandra Clemente, Diego Luciano Sasson, and Nicholas Trachter, "The Elasticity of Substitution in Demand for Non-Tradable Goods in Latin America: The Case of Argentina," Inter-American Development Bank, Research Network Working paper #R-485, August 2004.

Jeanne, Olivier and Anton Korinek, "Macroprudential Regulation Versus Mopping Up After The Crash," manuscript, July 2012.

Kaminsky, Graciela L., Carmen M. Reinhart, and Carlos A. Végh, "When It Rains, It Pours: Procyclical Capital Flows and Macroeconomic Policies," in Mark Gertler and Kenneth Rogoff, editors, *NBER Macroeconomics Annual 2004, Volume 19,* MIT Press, April 2005, pp. 11-61.

Korinek, Anton, "Excessive Dollar Borrowing in Emerging Markets: Balance Sheet Effects and Macroeconomic Externalities," manuscript, University of Maryland, 2010.

Lorenzoni, Guido, "Inefficient Credit Booms," *Review of Economic Studies 75,* 2008, 809-833.

Obstfeld, Maurice, and Kenneth Rogoff, *Foundations of International Macroeconomics,* Cambridge MA: The MIT Press, 1996.

Obstfeld, Maurice, Jay Shambaugh, and Alan Taylor, "Financial Stability, the Trilemma, and International Reserves," *American Economic Journal: Macroeconomics 2,* April 2010, 57-94.

Ostry, Jonathan D. and Carmen M. Reinhart, "Private Saving and Terms of Trade Shocks: Evidence from Developing Countries," *IMF Staff Papers,* September 1992, 495-517.

Ottonello, Pablo, "Optimal Exchange Rate Policy Under Collateral Constraints and Wage Rigidity," manuscript, Columbia University, October 2012 .

Schmitt-Grohé, Stephanie, and Martín Uribe, "Pegs and Pain," Columbia University, November 2011a.

Schmitt-Grohé, Stephanie, and Martín Uribe, "Pegs, Downward Wage Rigidity, And Unemployment: The Role of Financial Structure," Columbia University, November 2011b.

Schmitt-Grohé, Stephanie, and Martín Uribe, *"International Macroeconomics,"* textbook manuscript, Columbia University, 2012a.

Schmitt-Grohé, Stephanie, and Martín Uribe, "Managing Currency Pegs," *American Economic Review Papers and Proceedings 102,* May 2012b, 192-197.

Schmitt-Grohé, Stephanie, and Martín Uribe, "The Case for Temporary Inflation In the Eurozone," Manuscript, Columbia University, 2012c.

Uribe, Martín, "Exchange-Rate-Based Inflation Stabilization: The Initial Real Effects of Credible Plans," *Journal of Monetary Economics 39,* June 1997, 197-221.

Uribe, Martín, "On Overborrowing," *American Economic Review Papers and Proceedings 96,* May 2006, 417-421.

Uribe, Martín, "Individual Versus Aggregate Collateral Constraints and the Overborrowing Syndrome," NBER working paper 12260, May 2007.