Downward Nominal Wage Rigidity, Currency Pegs, and Involuntary Unemployment

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This paper analyzes the inefficiencies arising from the combination of fixed exchange rates, nominal rigidity, and free capital mobility. We document that nominal wages are downwardly rigid in emerging countries. We develop an open-economy model that incorporates this friction. The model predicts that the combination of a currency peg and free capital mobility creates a negative externality that causes overborrowing during booms and high unemployment during contractions. Optimal capital controls are shown to be prudential. For plausible calibrations, they reduce unemployment by around 5 percentage points. The optimal exchange rate policy eliminates unemployment and calls for large devaluations during crises.

I. Introduction

The combination of a fixed exchange rate and free capital mobility can be a mixed blessing. A case in point is the European currency union. Figure 1

This paper merges two earlier papers: "Pegs and Pain" and "Prudential Policy for Peggers" (Schmitt-Grohé and Uribe 2010, 2012). We thank Gianluca Benigno, Javier Bianchi, Ester Faia, Philip Harms, Olivier Jeanne, Robert Kollmann, Anna Kormilitsina, José L. Maia, Juan Pablo Nicolini, Chris Otrok, Jaume Ventura, Harald Uhlig (the editor), three anonymous referees, and seminar participants at numerous institutions for comments; Ozge Akinci, Ryan Chahrour, Stephane Dupraz, and Pablo Ottonello for excellent research assistance; and the National Science Foundation for research support.

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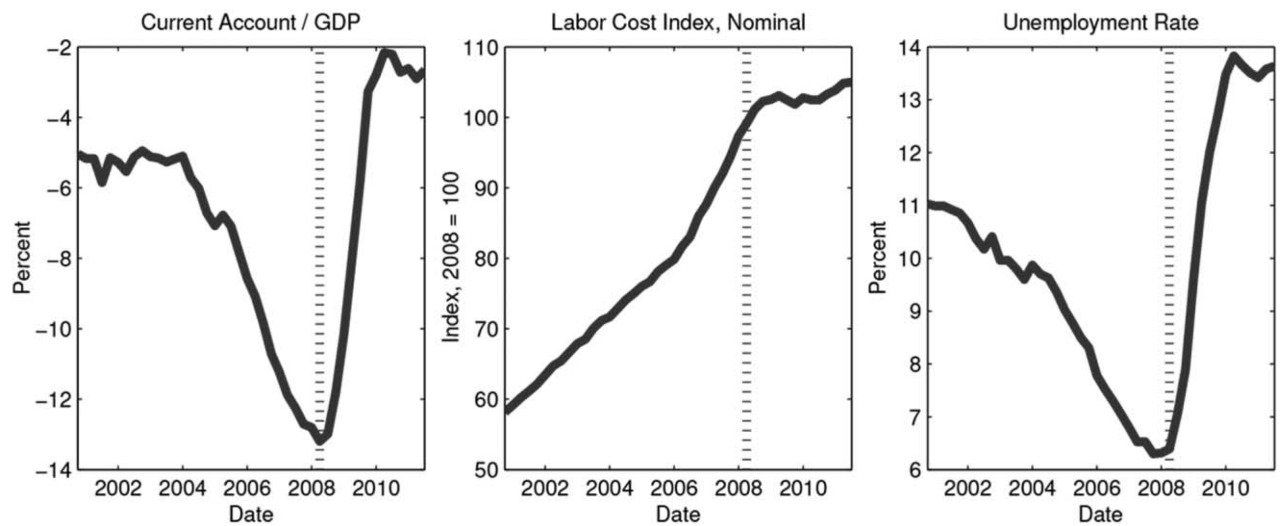

Fig. 1.—Boom-bust cycle in peripheral Europe: 2000–2011. Data Source: Eurostat. Sample period, 2000:Q4–2011:Q3. Data represent arithmetic mean of Bulgaria, Cyprus, Estonia, Greece, Ireland, Lithuania, Latvia, Portugal, Spain, Slovenia, and Slovakia. The vertical dotted line indicates 2008:Q2, the onset of the Great Contraction in Europe. Detailed data sources and country-by-country plots are available in online appendix A. The data are provided with the online materials of this paper. Color version available as an online enhancement.

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 were either on or pegging to the euro over the period 2000–2011. 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 global recession in 2008, 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. What is the optimal exchange rate policy in an open economy with downward nominal wage rigidity? What are the welfare costs of currency pegs vis-à-vis the optimal exchange rate policy in the presence of downward nominal wage rigidity? Can fixed exchange rate regimes benefit from imposing capital controls? If so, are optimal capital controls prudential in nature; that is, is it optimal to tax capital inflows during booms and subsidize them during contractions? How large are the welfare gains of optimal capital controls for peggers?

In this paper, we address these five questions both analytically and quantitatively. To this end, we develop a model of an open economy with downward nominal wage rigidity. The motivation for focusing on downward nominal wage rigidity is empirical. There exists a large literature suggesting that downward nominal wage rigidity is pervasive in developed countries. In this paper, we provide new evidence suggesting that this is also the case among emerging-market economies.

The model predicts an endogenous connection between macroeconomic volatility and the mean level of unemployment. This connection is due to the nature of the assumed labor contract, according to which employment is demand determined during contractions but supply and demand determined during booms. As a result, involuntary unemployment emerges during downturns and full employment during booms. Consequently, aggregate fluctuations cause unemployment on average. Importantly, the average level of unemployment is increasing in the amplitude of the business cycle, opening the door to large welfare gains from macroeconomic stabilization policy.

The paper establishes that the combination of downward nominal wage rigidity, a fixed exchange rate, and free capital mobility creates a negative externality. The externality causes overborrowing during booms and excessive unemployment during contractions. The nature of the 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.

The existence of the externality creates a rationale for government intervention. We consider two types of policy intervention. First, we study interventions that achieve the first-best allocation. We show that the first-best allocation can be brought about either via exchange rate policy or via labor or production subsidies at the level of the firm financed by income taxes levied at the level of the household.

The optimal exchange rate policy consists in engineering large devaluations of the domestic currency during contractions. The purpose of these devaluations is to reduce the real value of wages. Importantly, these optimal devaluations are not of the beggar-thy-neighbor type because they do not aim to foster exports by altering the terms of trade. Rather, they are geared toward correcting the distortion in the labor market created by downward nominal wage rigidity. Versions of the model calibrated to emerging-country data predict that boom-bust episodes like the ones that took place in Argentina in 2001 or in peripheral Europe in 2008, in which output falls by two standard deviations from peak to trough over a time span of 10 quarters, call for devaluations of about 100 percent.

The second type of policy intervention we consider is one in which the policy maker is constrained to stick to a currency peg and faces limitations to change domestic fiscal policy. Instead, he resorts to imposing capital controls. We show that in fixed exchange rate economies the Ramsey-optimal capital control tax is prudential in nature, as it restricts capital inflows in good times and subsidizes external borrowing in bad times. The 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 subsequent contractions. We show that the government determines the optimal capital control policy as the solution to a trade-off between intertemporal distortions caused by the capital controls themselves and static distortions caused by the combination of downward nominal wage rigidity and a fixed exchange rate.

Quantitative analysis based on a plausible calibration of the model to emerging-country data suggests that currency pegs coupled with free capital mobility lead to high average levels of unemployment of more than 8 percent. In turn, large levels of unemployment translate into large welfare losses. Capital controls are shown to be highly effective at curbing overborrowing during booms and reducing unemployment during busts. In the baseline calibration, optimal capital controls reduce the average rate of unemployment from over 8 percent to below 3 percent. This means that the trade-off faced by the policy maker between alleviating the static distortions in the labor markets and interfering with the efficient intertemporal allocation of tradable absorption through capital controls is resolved largely in favor of the former.

This paper is 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. A number of studies have analyzed the welfare consequences of currency pegs in the context of models with nominal rigidities (e.g., Kollmann 2002; Galí and Monacelli 2005). There is also a body of work on the role of capital controls as a stabilization instrument. A strand of this 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; Caballero and Lorenzoni 2009; Korinek 2010; Benigno et al. 2011; Bianchi 2011; Bianchi and Mendoza 2012; Jeanne and Korinek 2013). Another line of work is based on the classical trade theoretic argument that 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 (e.g., Obstfeld and Rogoff 1996; Costinot, Lorenzoni, and Werning 2011). 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 II develops the theoretical model. Section III identifies the negative externality arising from the combination of downward nominal wage rigidity, fixed exchange rates, and free capital mobility. Sections IV, V, and VI characterize equilibrium dynamics under optimal exchange rate policy, optimal fiscal policy under a currency peg, and optimal capital control policy under a currency peg, respectively. Section VII shows by means of an analytical example that optimal capital controls are prudential. Section VIII presents empirical evidence on downward nominal wage rigidity in emerging countries. Section IX analyzes quantitatively the adjustment of the economy to a boom-bust cycle under the various policy arrangements described above. It also contains the main quantitative results on the effects of the aforementioned policy interventions on overborrowing, average unemployment, and welfare. Section X presents conclusions.

II. An Open Economy with Downward Nominal Wage Rigidity

We develop a model of a small open economy in which nominal wages are downwardly rigid. The model features two types of goods, tradables and nontradables. The economy is driven by two exogenous shocks, a country–interest rate shock and a terms-of-trade shock.

A. Households

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

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(c_t), \tag{1}$$

where c_t denotes consumption, U is a strictly increasing and concave period utility function, and $\beta \in (0, 1)$ is the subjective discount factor. The symbol $\mathbb{E}_t$ denotes the mathematical expectations operator conditional on 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 has the form

$$c_t = A(c_t^T, c_t^N), \tag{2}$$

where $A(\cdot, \cdot)$ is an increasing, concave, and linearly homogeneous function.

We assume full liability dollarization. Specifically, households have access to a one-period, internationally traded, state-noncontingent 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

$$P_t^T c_t^T + P_t^N c_t^N + E_t d_t = P_t^T y_t^T + W_t h_t + \Phi_t + \frac{E_t d_{t+1}}{1 + r_t}, \tag{3}$$

where P_t^T denotes the nominal price of tradable goods, P_t^N the nominal price of nontradable goods, E_t the nominal exchange rate defined as the domestic currency price of one unit of foreign currency, y_t^T the endowment of traded goods, W_t the nominal wage rate, h_t hours worked, and Φ_t nominal profits from the ownership of firms. The variables r_t and y_t^T are assumed to be exogenous and stochastic. Movements in y_t^T can be interpreted either as shocks to the physical availability of tradable goods or as shocks to the country's terms of trade.

Households supply inelastically $\bar{h}$ hours to the labor market each period. The assumption of an inelastic labor supply is motivated in part by microeconometric evidence (e.g., Blundell and MaCurdy 1999) and macroeconometric evidence from models with nominal rigidities (e.g., Smets and Wouters 2007; Justiniano, Primiceri, and Tambalotti 2010) suggesting that the labor supply elasticity is near zero. A second reason for assuming an inelastic labor supply is that it makes the workings of our two-sector model more transparent. In section G.5 of the online appendix, we relax this assumption by endogenizing the labor supply decision. Because of the presence of downward nominal wage rigidity, households may not be able to sell all of the hours they supply. As a result, households take employment, $h_t \leq \bar{h}$, as exogenously given.

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

$$d_{t+1} \leq \bar{d}, \tag{4}$$

where $\bar{d}$ denotes the natural debt limit.

We assume that the law of one price holds for tradables. Specifically, letting P_t^{T*} denote the foreign currency price of tradables, the law of one price implies that $P_t^T = P_t^{T*} E_t$. We further assume that the foreign currency price of tradables is constant and normalized to unity, $P_t^{T*} = 1$. In the quantitative analysis, we relax this assumption. Thus, we have that the nominal price of tradables equals the nominal exchange rate, $P_t^T = E_t$.

Households choose contingent plans $\{c_t, c_t^T, c_t^N, d_{t+1}\}$ to maximize (1) subject to (2)–(4) taking as given P_t^T, P_t^N, E_t, W_t, h_t, Φ_t, r_t, and y_t^T. Letting

$$p_t \equiv \frac{P_t^N}{P_t^T}$$

denote the relative price of nontradables in terms of tradables and using the fact that $P_t^T = E_t$, the optimality conditions associated with this problem are (2)–(4) and

$$\frac{A_2(c_t^T, c_t^N)}{A_1(c_t^T, c_t^N)} = p_t, \tag{5}$$

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

$$\begin{aligned} \frac{\lambda_t}{1 + r_t} &= \beta \mathbb{E}_t \lambda_{t+1} + \mu_t, \\ \mu_t &\geq 0, \\ \mu_t(d_{t+1} - \bar{d}) &= 0, \end{aligned} \tag{6}$$

where λ_t / P_t^T and μ_t denote the Lagrange multipliers associated with (3) and (4), respectively.

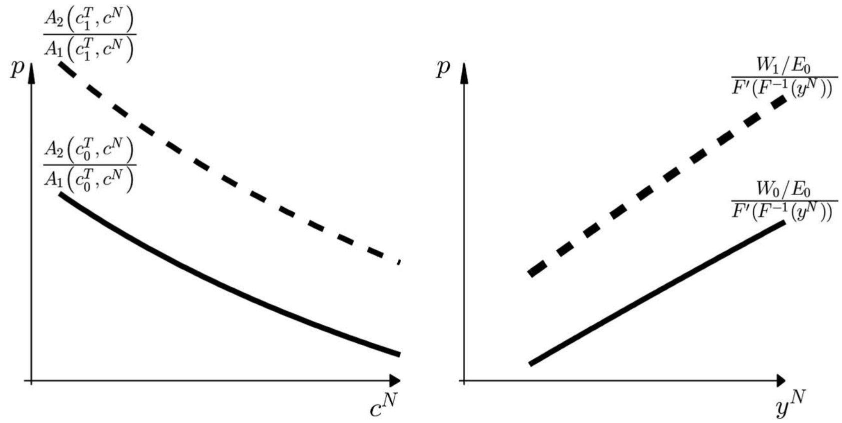

FIG. 2.—Demand and supply schedules of nontradable goods

Equation (5) 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 the left panel of figure 2 with a downward-sloping solid line. An increase in the absorption of tradables shifts the demand schedule up and to the right, reflecting normality. Such a shift is shown with a dashed downward-sloping line in the left panel of figure 2 for an increase in traded consumption from c_0^T to $c_1^T > c_0^T$. Absorption of tradables can be viewed as a shifter of the demand for nontradables. Of course, c_t^T is itself an endogenous variable, which is determined simultaneously with all other endogenous variables of the model.

B. Firms

Nontraded output, denoted y_t^N, is produced by perfectly competitive firms. Each firm operates a production technology given by $y_t^N = F(h_t)$, 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 input to maximize profits, given by $\Phi_t \equiv P_t^N F(h_t) - W_t h_t$. The optimality condition associated with this problem is $P_t^N F'(h_t) = W_t$. Dividing both sides by P_t^T and using the facts that $P_t^T = E_t$ and $h_t = F^{-1}(y_t^N)$ yields a supply schedule of nontradable goods of the form

$$p_t = \frac{W_t/E_t}{F'(F^{-1}(y_t^N))}.$$

This supply schedule is depicted with a solid upward-sloping line in the right panel of figure 2. Ceteris paribus, the higher the relative price of the nontraded good, the larger the supply of nontradable goods. Also, all other things equal, the higher the labor cost, W_t/E_t, the smaller the supply of nontradables at each level of the relative price p_t. That is, an increase in the nominal wage rate, holding constant the nominal exchange rate, causes the supply schedule to shift up and to the left. The right panel of 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 $W_1 > W_0$, holding the nominal exchange rate constant at E_0. Similarly, a currency devaluation, holding the nominal wage constant, shifts the supply schedule down and to the right (not shown). Intuitively, a devaluation that is not accompanied by a change in nominal wages reduces the real labor cost, thereby inducing firms to increase the supply of nontradable goods for any given relative price.

C. *Downward Nominal Wage Rigidity*

The central friction in the model is downward nominal wage rigidity. Specifically, we impose that

$$W_t \geq \gamma W_{t-1}, \quad \gamma > 0. \tag{7}$$

The parameter γ governs the degree of downward nominal wage rigidity. The higher γ is, the more downwardly rigid nominal wages are. This setup nests the cases of absolute downward rigidity when $\gamma \geq 1$ and full wage flexibility when $\gamma = 0$. In Section VIII, we present empirical evidence suggesting that γ is close to unity in low-inflation emerging economies.

The presence of downwardly rigid nominal wages implies that the labor market will in general not clear. Instead, involuntary unemployment, given by $\bar{h} - h_t$, will be a regular feature of this economy. Actual employment must satisfy

$$h_t \leq \bar{h} \tag{8}$$

at all times. At any point in time, wages and employment must satisfy the slackness condition

$$(\bar{h} - h_t)(W_t - \gamma W_{t-1}) = 0. \tag{9}$$

This condition states that periods of unemployment ($h_t < \bar{h}$) must be accompanied by a binding wage constraint. It also states that when the wage constraint is not binding ($W_t > \gamma W_{t-1}$), the economy must be in full employment ($h_t = \bar{h}$).

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 compression of wage increases in anticipation of future adverse shocks. The empirical evidence, however, suggests that strategic wage compression may have played a relatively minor role in recent boom-bust episodes. For instance, as documented in figure 1, nominal hourly wages in the periphery of the euro zone increased over 60 percent during the boom of 2000–2008 in spite of low inflation and virtually no growth in total factor productivity.[1]

D. Equilibrium

In equilibrium, the market for nontraded goods must clear at all times. That is, the condition

$$c_t^N = y_t^N$$

must hold for all t. Combining this condition, the production technology for nontradables, the household's budget constraint, and the definition of firms' profits, we obtain the market-clearing condition for traded goods,

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

Letting $w_t \equiv W_t/E_t$ denote the real wage in terms of tradables and

$$\epsilon_t \equiv \frac{E_t}{E_{t-1}}$$

the gross rate of devaluation of the domestic currency, we define an equilibrium as follows.

Definition 1 (Equilibrium). An equilibrium is a set of stochastic processes $\{c_t^T, h_t, w_t, d_{t+1}, \lambda_t, \mu_t\}_{t=0}^{\infty}$ satisfying

$$c_t^T + d_t = y_t^T + \frac{d_{t+1}}{1 + r_t}, \tag{10}$$

$$d_{t+1} \leq \bar{d}, \tag{11}$$

[1] Barkbu, Rahman, and Valdés (2012) show that for the euro area as a whole, total factor productivity grew by less than 0.2 percent per year between 2000 and 2010. Productivity growth in the periphery of Europe was even weaker. According to data from the EU Klems Growth and Productivity Account Project, between 2000 and 2007, value-added total factor productivity fell by 4 percent in Spain and by 1 percent in Ireland.

$$\mu_t \geq 0, \tag{12}$$

$$\mu_t(d_{t+1} - \bar{d}) = 0, \tag{13}$$

$$\lambda_t = U'(A(c_t^T, F(h_t)))A_1(c_t^T, F(h_t)), \tag{14}$$

$$\frac{\lambda_t}{1 + r_t} = \beta \mathbb{E}_t \lambda_{t+1} + \mu_t, \tag{15}$$

$$\frac{A_2(c_t^T, F(h_t))}{A_1(c_t^T, F(h_t))} = \frac{w_t}{F'(h_t)}, \tag{16}$$

$$w_t \geq \gamma \frac{w_{t-1}}{\epsilon_t}, \tag{17}$$

$$h_t \leq \bar{h}, \tag{18}$$

$$(h_t - \bar{h})\left(w_t - \gamma \frac{w_{t-1}}{\epsilon_t}\right) = 0, \tag{19}$$

given an exchange rate policy, $\{\epsilon_t\}_{t=0}^{\infty}$, initial conditions w_{-1} and d_0, and exogenous stochastic processes $\{r_t, y_t^T\}_{t=0}^{\infty}$.

We characterize analytically equilibrium under four alternative policy regimes: a currency peg with free capital mobility, the optimal exchange rate policy, optimal fiscal policy under currency pegs, and optimal capital controls under currency pegs.

III. Currency Pegs with Free Capital Mobility

A currency peg is an exchange rate policy in which the nominal exchange rate is fixed. The gross devaluation rate therefore satisfies

$$\epsilon_t = 1, \tag{20}$$

for $t \geq 0$. Under a currency peg, the economy is subject to two nominal rigidities. One is policy induced: The nominal exchange rate, E_t, is kept fixed by the monetary authority. The second is structural and is given by the downward rigidity of the nominal wage W_t. The combination of these two nominal rigidities results in a real rigidity. Specifically, the real wage, w_t, is downwardly rigid and, when falling, moves sluggishly at a rate no larger than $1 - \gamma$. The labor market is therefore, in general, in disequilibrium and features involuntary unemployment. Unemployment is a function of the amount by which the past real wage exceeds the current full-employment real wage. It follows that under a currency peg, the past real wage, w_{t-1}, becomes a relevant state variable for the economy.

A. *A Peg-Induced Externality*

The combination of downward nominal wage rigidity and a currency peg creates a negative externality. The nature of this externality is that in periods of economic expansion, elevated demand for nontradables drives nominal (and 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.

Figure 3 illustrates the peg-induced externality by considering the adjustment of the economy to a boom-bust episode. Because in equilibrium $c_t^N = y_t^N = F(h_t)$, the figure plots the demand and supply schedules for nontraded goods in terms of employment in the nontraded sector, so that the horizontal axis measures h_t. The intersection of the demand and supply schedules, therefore, indicates the equilibrium demand for labor, given c_t^T and W_t/E_t. The figure also shows with a dotted vertical line the

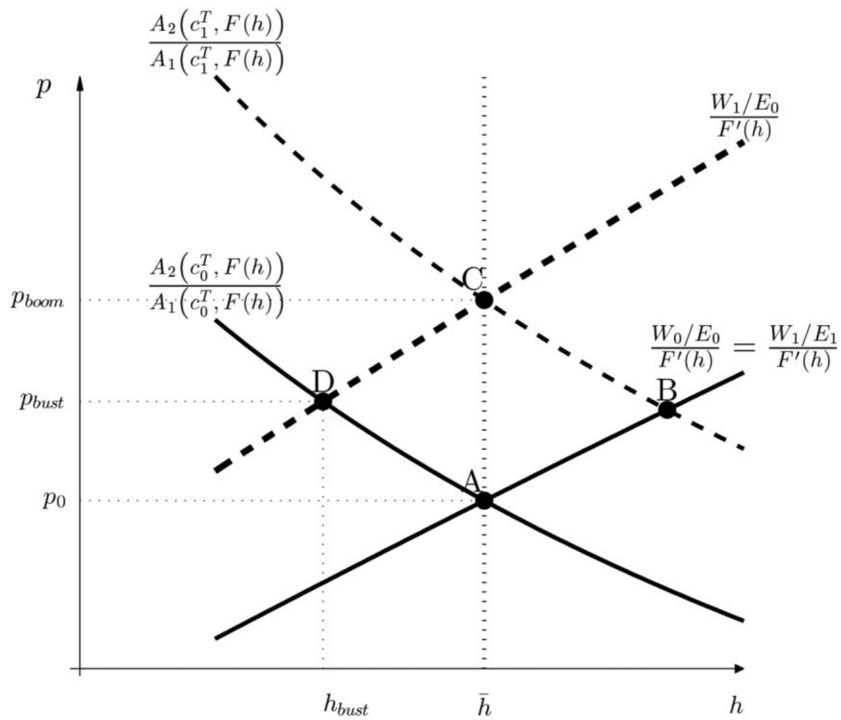

FIG. 3.—Adjustment to a boom-bust episode under a currency peg. The figure is drawn under the assumption that $\gamma = 1$.

labor supply, $\bar{h}$. Suppose that the initial position of the economy is at point A, where the labor market is operating at full employment, $h_t = \bar{h}$. Suppose that in response to a positive external shock, such as a decline in the country interest rate, traded absorption increases from c_0^T to $c_1^T > c_0^T$, 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 point B the demand for labor would exceed the available supply of labor $\bar{h}$. The excess demand for labor drives up the nominal wage from W_0 to $W_1 > W_0$, causing the supply schedule 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. The transition from points A to C happens instantaneously because nominal wages are upwardly flexible. Although the economy is enjoying full employment, the increase in nominal wages is a harbinger of bad things to come.

Suppose now that the positive external shock fades away and that, as a consequence, absorption of tradables goes back to its normal level c_0^T. The decline in c_t^T shifts the demand schedule back to its original position, indicated by the downward-sloping solid line. However, the economy does not return to point A. Because of downward nominal wage rigidity, the nominal wage stays at W_1, and because of the currency peg, the nominal exchange rate remains at E_0. As a result, the supply schedule continues to be the broken upward-sloping line. The new intersection is at point D. There, the economy suffers involuntary unemployment equal to $\bar{h} - h_{\text{bust}}$. If individual households could internalize the fact that consumption booms lead to excessive wage growth and unemployment once the boom is over, they might choose to restrain their appetite for tradable goods during the boom. This is the precise nature of the peg-induced externality.

B. Volatility and Mean Unemployment

The present model implies an endogenous connection between the amplitude of the cycle and the average levels of involuntary unemployment and output. This connection opens the door to large welfare gains from optimal stabilization policy and is rooted in the fact that under a currency peg the economy adjusts asymmetrically to positive and negative external shocks. The adjustment to positive external shocks is efficient, as nominal wages adjust upward to ensure that firms are on their labor demand schedule and households on their labor supply schedule. In sharp contrast, the adjustment to negative external shocks is inefficient, as nominal wages fail to fall, forcing households off their labor supply schedule and generating involuntary unemployment. It follows that over the business cycle, the model economy fluctuates between periods of full employment and an efficient level of production and periods of involuntary unemployment and inefficiently low levels of production. Therefore, the average levels of involuntary unemployment and nontraded output depend on the amplitude of the business cycle. That is, in this model, mean unemployment is increasing in the variance of the underlying shocks. This property of the model obtains even if wage rigidity is symmetric (i.e., even if nominal wages are equally rigid upwardly and downwardly). The reason is that in the present model employment is determined by the smaller of demand and supply, as opposed to demand alone, as is the case in existing sticky-wage models in the Erceg, Henderson, and Levin (2000) and Galí (2011) tradition. Asymmetric wage rigidity exacerbates the connection between the volatility of the underlying shocks and the average level of involuntary unemployment.

IV. Optimal Exchange Rate Policy

Consider an exchange rate policy in which the central bank always sets the devaluation rate to ensure full employment in the labor market, that is, to ensure that $h_t = \bar{h}$, for all $t \geq 0$. We refer to this exchange rate arrangement as the full-employment exchange rate policy and will show that it supports the Pareto-optimal allocation. The equilibrium dynamics associated with the full-employment exchange rate policy are illustrated in figure 3. Suppose that, after being hit by a negative external shock, the economy is stuck at point D with involuntary unemployment equal to $\bar{h} - h_{\text{bust}}$. At point D, the desired demand for tradables is c_0^T, the nominal wage is W_1, and the nominal exchange rate is E_0. Suppose that the central bank were to devalue the domestic currency so as to deflate the purchasing power of nominal wages to a point consistent with full employment. That is, suppose that the central bank sets the exchange rate at the level $E_1 > E_0$ satisfying

$$(W_1/E_1)/F'(\bar{h}) = A_2(c_0^T, F(\bar{h}))/A_1(c_0^T, F(\bar{h})).$$

In this case the supply schedule would shift down and to the right, intersecting the demand schedule at point A, where unemployment is nil ($h = \bar{h}$). Under the full-employment exchange rate policy, the relative price of nontradables falls from p_{boom} at the peak of the cycle to p_0 after the negative external shock. By contrast, if the central bank had kept the exchange rate fixed, the relative price of nontradables would have fallen by less, namely, from p_{boom} to p_{bust}. The reason why in the currency peg economy firms are reluctant to implement sufficiently large price cuts is that real wages, and therefore labor costs, remain as high as they were during the boom. By contrast, the devaluation lowers the real cost of labor, making it viable for firms to slash prices. In turn, because under the peg prices remain high, households do not receive a strong enough signal to switch expenditures away from tradables and toward nontradables in a magnitude compatible with full employment.

The full-employment policy amounts to setting the devaluation rate to ensure that the real wage equals the full-employment real wage. We denote the full-employment real wage by $\omega(c_t^T)$, where the function $\omega(c_t^T)$ is given by

$$\omega(c_t^T) \equiv \frac{A_2(c_t^T, F(\bar{h}))}{A_1(c_t^T, F(\bar{h}))} F'(\bar{h}). \tag{21}$$

The assumed properties of the aggregator function A ensure that the function $\omega(\cdot)$ is strictly increasing in c_t^T.

The full-employment exchange rate policy stipulates that should the nominal value of the full-employment real wage evaluated at last period's nominal exchange rate, $\omega(c_t^T)E_{t-1}$, fall below the lower bound γW_{t-1}, then the central bank devalues the domestic currency to ensure that $\omega(c_t^T)E_t \geq \gamma W_{t-1}$. That is, the devaluation rate makes the nominal wage, W_t, greater than or equal to its lower bound, γW_{t-1}, and at the same time guarantees that the real wage, w_t, equals the full-employment real wage $\omega(c_t^T)$. In general, any exchange rate policy satisfying

$$\epsilon_t \geq \gamma \frac{w_{t-1}}{\omega(c_t^T)} \tag{22}$$

ensures full employment at all times. All exchange rate policies pertaining to this family deliver the same real allocation and are therefore equivalent from a welfare point of view. Indeed, the real allocation induced by policies belonging to this family is Pareto optimal. The following proposition establishes these results.

Proposition 1. Any exchange rate policy satisfying condition (22) is consistent with a real allocation that exhibits full employment ($h_t = \bar{h}$) at all dates and states and is Pareto optimal.

Proof. See online appendix B.

The Pareto-optimal allocation, denoted $\{c_t^{To}, d_{t+1}^o\}_{t=0}^{\infty}$, is the solution to the following value function problem:

$$v^o(y_t^T, r_t, d_t) = \max_{\{c_t^T, d_{t+1}\}} \{U(A(c_t^T, F(\bar{h}))) + \beta \mathbb{E}_t v^o(y_{t+1}^T, r_{t+1}, d_{t+1})\} \tag{23}$$

subject to (10) and (11), where the function $v^o(y_t^T, r_t, d_t)$ represents the welfare level of the representative agent in state (y_t^T, r_t, d_t). The facts that under the optimal exchange rate policy aggregate dynamics can be described as the solution to a Bellman equation and that the past real wage, w_{t-1}, is not a relevant state variable in period t greatly facilitate the quantitative characterization of the model's predictions.

V. Optimal Fiscal Policy under a Currency Peg and Free Capital Mobility

Many observers have suggested the use of fiscal policy to ease the pains of currency pegs. However, advocates of active fiscal policy do not speak with a single voice. Some argue that the right medicine is fiscal restraint via tax increases and cuts in public expenditures. Others hold diametrically opposed views and argue that only widespread increases in government spending and tax cuts can offer pain relief. Our model suggests that both of these extreme views are misguided. Instead, the model suggests that the way to ease the pain of a currency peg by means of fiscal policy is more sophisticated in nature. In particular, optimal fiscal policy in the context of a currency peg can be implemented by a time-varying wage subsidy at the firm level, financed with income taxes at the household level.

Suppose that the exchange rate is pegged ($\epsilon_t = 1$) and that the government subsidizes employment at the firm level at the rate τ_t^h and levies income taxes at the household level at the rate τ_t^y. The sequential budget constraint of the household is then given by

$$c_t^T + p_t c_t^N + d_t = (1 - \tau_t^y)(y_t^T + w_t h_t + \phi_t) + \frac{d_{t+1}}{1 + r_t}, \tag{24}$$

where $\phi_t \equiv \Phi_t / E_t$ denotes real profits in terms of tradables. Note that the proportional income tax τ_t^y is nondistorting, because households take y_t^T, $w_t h_t$, and ϕ_t as given. Consequently, the first-order conditions of the household are as in the economy without income taxes (see Sec. II.A).

With the wage subsidy, profits of firms expressed in terms of tradables are given by $\phi_t = p_t F(h_t) - (1 - \tau_t^h) w_t h_t$. The optimality condition for profit maximization is

$$p_t = \frac{(1 - \tau_t^h) w_t}{F'(h_t)}. \tag{25}$$

We assume that the government consumes no goods, starts with no debt, and maintains a balanced budget period by period. Thus, its sequential budget constraint is given by

$$\tau_t^h w_t h_t = \tau_t^y (y_t^T + w_t h_t + \phi_t). \tag{26}$$

All other aspects of the model are as in the currency peg economy without taxes.

The Pareto-optimal equilibrium can be supported under a currency peg by setting the payroll subsidy τ_t^h as

$$\tau_t^h = \max\left\{0, 1 - \frac{\omega(c_t^T)}{\gamma w_{t-1}}\right\}. \tag{27}$$

The following proposition establishes this result.

PROPOSITION 2 (Optimal wage subsidy under a currency peg). Suppose that the exchange rate policy is characterized by a currency peg. Then, the labor subsidy given in equation (27) supports the Pareto-optimal allocation.

Proof. See online appendix C.

The intuition why a wage subsidy can implement the Pareto-optimal allocation is straightforward and is closely linked to how the optimal devaluation policy works. Equation (25) is the supply schedule of nontradables plotted in figure 3, with the after-subsidy real wage $(1 - \tau_t^h)w_t$ replacing W_t/E_t. Increases in τ_t^h shift this schedule down and to the right, just as devaluations do. In particular, when the economy is stuck at a point like D in the figure, with involuntary unemployment given by $\bar{h} - h_{\text{bust}}$, the government can induce a shift of the supply schedule down and to the right by increasing the labor subsidy τ_t^h, which reduces the labor cost perceived by firms. If the increase in the labor subsidy is of the right size, the equilibrium will be at point A, where full employment is restored. In this way, the fiscal authority can fully offset the real rigidity created by the combination of downward nominal wage rigidity and a currency peg.

It is straightforward to show that the Pareto-optimal allocation can also be brought about via consumption or sale subsidies in the nontraded sector at the same rate τ_t^h characterized in the above proposition.[2] Also, we assumed that the wage subsidy given in equation (27) is financed by a uniform income tax. However, it can be shown that the subsidy scheme can also be financed by an appropriate proportional tax on any individual source of income (labor income, $w_t h_t$, tradable income, y_t^T, profits, ϕ_t) or any combination thereof. Furthermore, these financing schemes work even when the labor supply is elastic. The reason is that the subsidy is positive only in states of the world in which, in the absence of the subsidy, households are off their labor supply schedule, or involuntarily unemployed.

It is clear from equation (27) that the optimal subsidy inherits the stochastic properties of the optimal devaluation rate studied in previous sections (see eq. [22]). Because, as we will see shortly, under plausible calibrations the optimal devaluation rate is found to be highly volatile at business cycle frequency, it follows that the fiscal alternative presented here may indeed introduce an impractically high level of volatility in labor subsidy or labor tax rates.

[2] In a more recent contribution, Farhi, Gopinath, and Itskhoki (2011) expand this idea to other economic environments.

VI. Optimal Capital Controls under a Currency Peg

In Section III.A, we established that the combination of a currency peg and downward nominal wage rigidity creates an externality. During episodes of large capital inflows, nominal wages rise, making the economy vulnerable to unemployment once capital inflows dry up, as nominal wages cannot adjust downwardly to equilibrate the labor market. Individuals understand this source of fragility but are too small to do anything about it. Thus, under a currency peg and free capital mobility, the economy overborrows during booms and suffers excessive unemployment during contractions. Consequently, the government has an incentive to intervene.

In this section, we study the efficacy of capital controls in remedying the peg-induced externality. We interpret the concept of capital controls broadly, as regulations of cross-border financial flows. For instance, the set of financial reform measures developed by the Basel Committee on Banking Supervision, known as 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 possible arrangements governing flows of financial capital across borders, like those existing in the European Union.

Specifically, we explore the possibility that the government acts prudentially by imposing capital controls during booms. Such a policy would tend to curb capital inflows and in that way contain the rise in nominal wages and limit the size of involuntary unemployment once the boom is over. Our approach is not to assume that capital controls are prudential, but rather to investigate whether prudential capital control policy emerges endogenously as a Ramsey-optimal outcome.

The intuition for why the government may wish to use capital controls in a prudential manner is illustrated in figure 4. Suppose that the economy starts at point A. At that point traded consumption is equal to c_0^T and the economy enjoys full employment. Assume now that the economy experiences a temporary decrease in the country interest rate followed by an increase, which causes a boom-bust response in c^T. Assume that in the absence of capital controls, consumption of tradables rises from c_0^T to $c_1^T > c_0^T$ when the country interest rate falls and then declines back to c_0^T once the country interest rate rises. As discussed earlier, in this case the economy moves from point A to point C during the boom and then from point C to point D in the bust. During the boom, nominal wages rise from W_0 to $W_1 > W_0$. In the bust, the economy experiences involuntary unemployment in the amount of $\bar{h} - h_{\text{bust}}$ because real wages are stuck at W_1/E_0 and downward nominal wage rigidity in combination with the currency peg prevents real wages from falling to a level consistent with full employment.

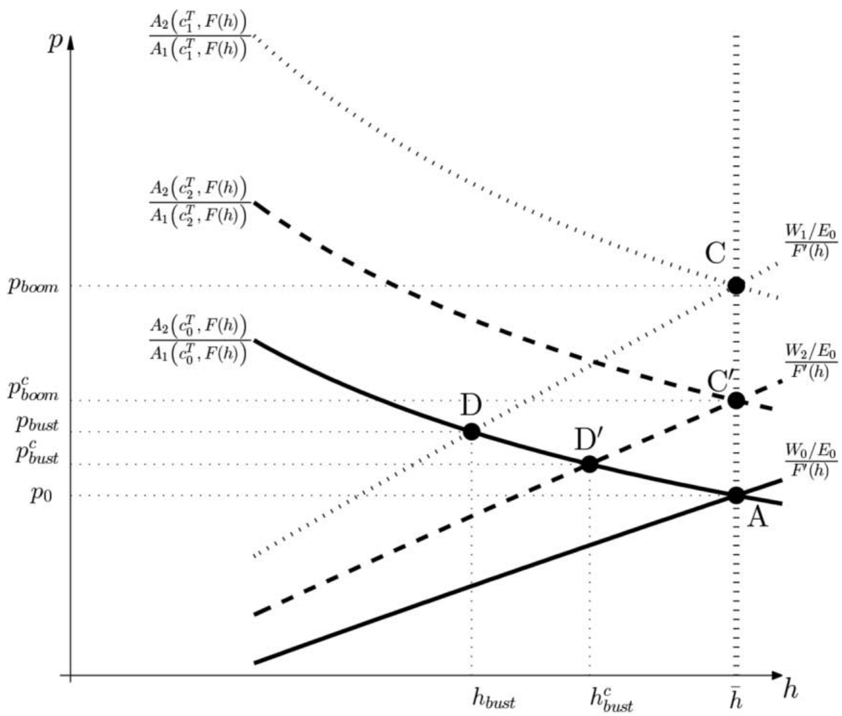

FIG. 4.—Prudential capital control policy. The figure is drawn under the assumption that $\gamma = 1$.

Consider now the case in which the government implements capital control taxes in response to the initial interest rate decline and that as a result of these taxes, the increase in traded consumption is smaller. Specifically, assume that traded consumption now increases from c_0^T to $c_2^T < c_1^T$. The demand for nontradables, shown with a broken downward-sloping line in figure 4, shifts up and to the right. As a result nominal wages increase to W_2 and the nontradables supply schedule, shown with a broken upward-sloping line, shifts up and to the left. The new intersection of the demand and supply schedules is at point C', where the economy enjoys full employment. Because the shift in the demand schedule in the presence of capital controls is smaller than in their absence, nominal wages rise by less, that is, $W_2 < W_1$. Assume again that when the positive external shock fades away, consumption of tradables falls back to c_0^T. The resulting demand schedule is thus the same as the initial one, given by the solid downward-sloping line in figure 4. The supply schedule (the upward-sloping broken line) does not shift because as a result of downward nominal wage rigidity, nominal wages cannot decline, that is, wages remain at W_2, and as a result of the currency peg, the exchange rate cannot change, that is, it remains at E_0. The new intersection of the demand and supply schedules is at point D', where $\bar{h} - h^c_{\text{bust}}$ workers are involuntarily unemployed. However, the level of unemployment at D' is lower than at D. It follows that by imposing capital controls in response to a positive external shock, that is to say, by imposing capital controls in a prudential manner, the government is able to reduce the amount of unemployment that occurs once the positive external shock is over.

But this government intervention comes at the cost of bringing about an inefficient allocation of traded consumption over time. For capital controls distort the interest rate perceived by domestic households. The imposition of capital controls induces households not to take full advantage of the cheaper cost of borrowing during the boom and not to reduce their absorption of tradables sufficiently once the interest rate rises. The figure illustrates the benefits in terms of lower unemployment that capital controls can bring. But the figure does not capture the costs in terms of a suboptimal time path of tradable consumption. To analyze the trade-off between less unemployment and an inefficient allocation of traded consumption over time, we next characterize Ramsey-optimal capital control policies more formally.

Assume that the government taxes external debt at the proportional rate τ_t^d and rebates this source of revenue via a proportional income subsidy denoted τ_t^y. The budget constraint of the household is then given by

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

We note again that because all sources of income—y_t^T, $w_t h_t$, and ϕ_t—are taken as exogenous by the household, the income subsidy used to rebate the revenues from capital controls is nondistorting. The introduction of a capital control tax changes the household's first-order condition for holdings of foreign assets to

$$\lambda_t \frac{1 - \tau_t^d}{1 + r_t} = \beta \mathbb{E}_t \lambda_{t+1} + \mu_t. \tag{28}$$

According to this expression, the effective gross interest rate on debt holdings between periods t and $t + 1$ perceived by households is $(1 + r_t)/(1 - \tau_t^d)$, which is greater than the gross country interest rate, $1 + r_t$, when the government imposes capital controls, that is, when $\tau_t^d >$ 0. Observe that the effective interest rate, $(1 + r_t)/(1 - \tau_t^d)$, like the country interest rate, $1 + r_t$, is in the information set of period t.

Thus, the capital control policy considered here preserves the state-noncontingent nature of external debt.

The government is assumed to be benevolent and to be endowed with full commitment. We therefore refer to the government as the Ramsey planner. We assume that the government pegs the currency and cannot use labor subsidies of the type studied in Section V. The budget constraint of the government is therefore given by

$$\tau_t^y(y_t^T + w_t h_t + \phi_t) = \frac{\tau_t^d d_{t+1}}{1 + r_t}. \tag{29}$$

The policy variable τ_t^d can take positive or negative values. In the former case it represents a tax on capital inflows and in the latter a subsidy.

Because the monetary authority pegs the currency at all times, equilibrium conditions (17) and (19) become, respectively,

$$w_t \geq \gamma w_{t-1} \tag{30}$$

and

$$(h_t - \bar{h})(w_t - \gamma w_{t-1}) = 0. \tag{31}$$

We then have the following definition of equilibrium in the economy with capital controls.

Definition 2 (Equilibrium with capital controls and a currency peg). Under capital controls and a currency peg, an equilibrium is a set of stochastic processes $\{c_t^T, h_t, w_t, d_{t+1}, \lambda_t, \mu_t, \tau_t^y\}_{t=0}^{\infty}$ satisfying (10)–(14), (16), (18), and (28)–(31), given a capital control policy $\{\tau_t^d\}_{t=0}^{\infty}$, initial conditions w_{-1} and d_0, and exogenous stochastic processes $\{r_t, y_t^T\}_{t=0}^{\infty}$.

The Ramsey planner's optimization problem consists in choosing a tax scheme $\{\tau_t^d\}$ to maximize the household's lifetime utility function (1) subject to the equilibrium conditions listed in definition 2. The strategy we follow to characterize the Ramsey allocation is to drop from the Ramsey planner's problem all constraints except for (10), (11), (16), (18), and (30) and then show that the solution to this less constrained problem satisfies the omitted constraints.

Accordingly, the less constrained Ramsey problem (LCP) is given by

$$\max_{\{c_t^T, d_{t+1}, h_t, w_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(A(c_t^T, F(h_t)))$$

subject to (10), (11), (16), (18), and (30), given d_0, w_{-1}, and the stochastic processes $\{r_t, y_t^T\}_{t=0}^{\infty}$.

We now show that the allocation $\{c_t^T, d_{t+1}, h_t, w_t\}_{t=0}^{\infty}$ that solves the LCP satisfies the constraints of the original Ramsey problem listed in definition 2. To see this, use the LCP allocation to construct λ_t to satisfy (14).

Next, set $\mu_t = 0$ for all t.[3] It follows that (12) and (13) are satisfied. Now construct τ_t^d to satisfy (28) and τ_t^y to satisfy (29). It remains to be shown that the allocation that solves the LCP satisfies the slackness condition (31). To see that this is the case, consider the following proof by contradiction. Suppose, contrary to what we wish to show, that the solution to the LCP implies $h_t < \bar{h}$ and $w_t > \gamma w_{t-1}$ at some date $t' \geq 0$. Consider now a perturbation to the allocation that solves the LCP consisting in a small increase in hours at time t' from $h_{t'}$ to $\tilde{h}_{t'} \leq \bar{h}$. Clearly, this perturbation does not violate the resource constraint (10), since hours do not enter in this equation. From (16) we have that the real wage falls to

$$\tilde{w}_{t'} \equiv \frac{A_2(c_{t'}^T, F(\tilde{h}_{t'}))}{A_1(c_{t'}^T, F(\tilde{h}_{t'}))} F'(\tilde{h}_{t'}) < w_{t'}$$

(recall that the expression in the middle is decreasing in hours). Because A_1, A_2, and F' are continuous functions, expression (30) is satisfied provided that the increase in hours is sufficiently small. In period $t' + 1$, restriction (30) is satisfied because $\tilde{w}_{t'} < w_{t'}$. We have therefore established that the perturbed allocation satisfies the restrictions of the LCP. 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 (31) cannot be a solution to the LCP. This completes the proof that the allocation that solves the LCP is also feasible in the Ramsey planner's problem. It follows that the allocation that solves the LCP is indeed the Ramsey-optimal allocation. We summarize this result in the following proposition.

PROPOSITION 3 (Optimal capital controls under a currency peg). Let $\{c_t^{T^c}, d_{t+1}^c, h_t^c, w_t^c\}_{t=0}^{\infty}$ be the allocation associated with the Ramsey-optimal capital control policy in the economy with a currency peg. Then $\{c_t^{T^c}, d_{t+1}^c, h_t^c, w_t^c\}_{t=0}^{\infty}$ is the solution to the problem of maximizing (1) subject to (10), (11), (16), (18), and (30), given d_0, w_{-1}, and the stochastic processes $\{r_t, y_t^T\}_{t=0}^{\infty}$.

A corollary of this proposition is that one can characterize the Ramsey allocation as the solution to the following Bellman equation problem:

$$v^c(y_t^T, r_t, d_t, w_{t-1}) = \max[U(A(c_t^T, F(h_t)) + \beta \mathbb{E}_t v^c(y_{t+1}^T, r_{t+1}, d_{t+1}, w_t)] \tag{32}$$

[3] Note that in states in which the 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.

subject to (10), (11), (16), (18), and (30), where $v^c(y_t^T, r_t, d_t, w_{t-1})$ denotes the value function of the representative household. We exploit this formulation of the Ramsey problem in our quantitative analysis.

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, $c_t^T + p_t c_t^N$, 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 that will be in effect in period $t + 1$. One can show that the Ramsey allocation can be supported by a consumption tax 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. According to this expression, if the Ramsey-optimal capital control tax in period t is positive (the planner is discouraging borrowing), then the associated Ramsey-optimal consumption tax scheme stipulates a decline in the consumption tax rate between periods t and $t + 1$ so as to induce households to postpone consumption. Suppose now that the optimal capital control tax is positive on average, which we will show is the case in the calibrated economy studied in Section IX. Then, it is clear from the above formula that the associated optimal consumption tax rate converges asymptotically to a subsidy of 100 percent of consumption expenditure, or $\tau_t^c \rightarrow -1$. This suggests an advantage of capital control taxes over consumption taxes from a practical point of view.

We also note 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 externality created by the combination of downward nominal wage rigidity and a currency peg.

VII. The Optimality of Prudential Capital Controls under a Currency Peg: An Analytical Example

In this section, we present an analytical example showing the prudential nature of optimal capital controls. We characterize the optimal capital control policy in response to a temporary decline in the interest rate and show that the Ramsey policy calls for an increase in capital control taxes while the interest rate is low. This intervention discourages capital inflows, thereby attenuating the expansion in tradable absorption. The example highlights the cost of capital controls, which take the form of an inefficient intertemporal allocation of consumption, and their benefits, which take the form of lower involuntary unemployment once the boom is over.

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 0 with no outstanding debt, $d_0 = 0$, that the endowment of tradables, y^T, is constant over time, and that the real wage in period -1 equals αy^T. Consider a situation in which the economy is subject to a temporary interest rate decline in period 0. Specifically, suppose that $r_0 = \underline{r}$ and $r_t = r > \underline{r}$ for $t \neq 0$. 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 prior to the interest rate shock, with $d_t = 0$, $c_t^T = y^T$, and $h_t = c_t^N = 1$ for $t < 0$.

In online appendix D, we show that under optimal capital controls, all variables are constant over time starting in period 1. The constancy of all variables is a consequence of the fact that after period 0 the economy suffers no further disturbances and of the assumptions that $\beta(1 + r)$ and γ are both equal to unity. The former parameter restriction ensures the constancy of tradable consumption and the latter the constancy of the real wage. This result implies that capital controls are zero starting in period 1. Online appendix D further establishes that in period 0 the change in tradable consumption is nonnegative, that is, $c_0^T \geq y^T$, and thus capital inflows are nonnegative, that is, $d_1 \geq d_0 = 0$. Intuitively, the fall in the interest rate encourages international borrowing and consumption. In period 0, the economy enjoys full employment, $h_0 = 1$. This is natural, since low interest rates stimulate aggregate demand. Finally, online appendix D shows that starting in period 1, employment is given by $h_t = c_1^T / c_0^T \leq 1$, for $t \geq 1$. This expression says that unemployment is increasing in the contraction in aggregate demand in period 1. Unemployment is persistent because wages cannot fall ($\gamma = 1$).

With these results in hand, the Ramsey-optimal capital control problem simplifies to

$$\max_{\{c_0^T, c_1^T, d_1\}} \left[\ln c_0^T + \frac{\beta}{1 - \beta} \ln c_1^T + \frac{\alpha\beta}{1 - \beta} (\ln c_1^T - \ln c_0^T) \right]$$

subject to $d_1 \geq 0$, $c_0^T = y^T + [d_1/(1 + \underline{r})]$, and $c_1^T = y^T - [r d_1/(1 + r)]$. The optimality conditions associated with this problem are the above three constraints,

$$\frac{1}{1+\underline{r}}\frac{1}{c_0^T}-\beta\frac{1}{c_1^T}-\alpha\beta\left[\frac{1}{c_1^T}+\frac{1+r}{r(1+\underline{r})}\frac{1}{c_0^T}\right]\leq 0, \tag{33}$$

and the slackness condition

$$\left\{\frac{1}{1+\underline{r}}\frac{1}{c_0^T}-\beta\frac{1}{c_1^T}-\alpha\beta\left[\frac{1}{c_1^T}+\frac{1+r}{r(1+\underline{r})}\frac{1}{c_0^T}\right]\right\}d_1 = 0.$$

The first two terms of optimality condition (33) represent the trade-off that the representative household would face in an unregulated economy in deciding whether to take on an additional unit of debt in period 0. An additional unit of debt allows the household to consume $1/(1+\underline{r})$ units of goods in period 0. In period 1, the household must repay one unit of consumption to cancel the debt assumed in period 0. We refer to the first two terms as the private marginal utility of debt. The third term in (33) captures the externality created by the combination of downward nominal wage rigidity and a currency peg. It reflects the Ramsey planner's internalization of the fact that changes in consumption affect unemployment (recall that $h_t = c_1^T/c_0^T$ for all $t \geq 1$). This is an equilibrium effect that is not taken into account by individual consumers. We refer to the sum of the three terms as the social marginal utility of debt. Since the third term is negative, we have that the social marginal utility of debt is always lower than its private counterpart.[4]

Figure 5 plots the social marginal utility of debt as a function of debt with a solid line and the private marginal utility of debt with a broken line. The figure distinguishes two cases, $\alpha < r$ shown in the left panel and $\alpha > r$ shown in the right panel. It can be shown that when $\alpha < r$, the private and social marginal utilities of debt are both downward sloping. The intercept of the private marginal utility of debt is always positive, whereas the intercept of the social marginal utility of debt may be positive or negative. Recalling that the social marginal utility of debt is always below its private counterpart, the socially optimal level of debt (point S in the figure) is always lower than the privately optimal level of debt (point P in the figure). The Ramsey planner induces this outcome by applying capital controls in period 0. This intervention is prudential in nature because it takes place when the economy is booming. In this way, the planner ensures that the level of involuntary unemployment that emerges in period 1 (when the boom is over) is lower in the Ramsey-optimal equilibrium than in the private equilibrium.

[4] We thank two anonymous referees for suggesting this interpretation of the optimality condition of the Ramsey problem.

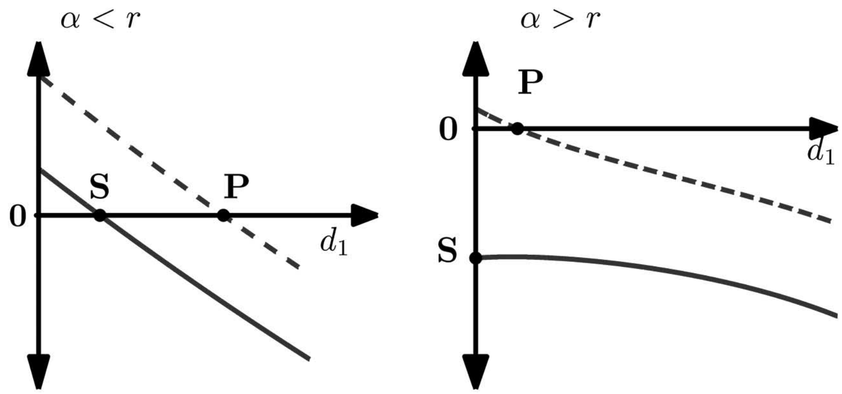

Fig. 5.—Private and social marginal utility of debt. Color version available as an online enhancement.

Consider now the case $\alpha > r$ shown in the right panel of figure 5. In this case the social marginal utility of debt is negative for all nonnegative values of debt. Thus, the socially optimal response to the decline in the interest rate is a corner solution featuring $d_1 = 0$ (point S in the figure). The Ramsey planner imposes capital controls such that the privately perceived (after-tax) interest rate $(1 + \underline{r})/(1 - \tau_0^d)$ equals $1 + r$.[5]

Thus, private households have no incentives to alter their consumption plans.[6] The benefit of this strong distortion of the intertemporal allocation of tradable absorption is full employment at all times. On the other hand, the private marginal utility of debt continues to be downward sloping with a positive intercept. As a consequence, the privately optimal level of debt (point P in the figure) is always positive and thus higher than the socially optimal level.[7]

In the case in which $\alpha > r$, the optimal capital control policy resolves the trade-off between intertemporal distortions and static distortions entirely in favor of eliminating all static distortions, that is, full employment

[5] Implementing the same real allocation via consumption taxes instead of capital controls would require a permanent consumption subsidy at the gross rate $(r - \underline{r})/(1 + r)$ starting in period 1.

[6] The change in the world interest rate does not generate a wealth effect because the desired net asset position prior to the change in the interest rate was nil.

[7] The intuition for why $\alpha > r$ is a sufficient condition for the corner solution of no increase in debt in response to a decline in the interest rate is as follows. An increase in debt implies a fall in employment of at least $1/c_0^T$ for all $t \geq 1$ (recall that $h_t = c_1^T/c_0^T$). This is equivalent to a decline in nontradable output of α/c_0^T for all $t \geq 1$. The value of this amount of nontradables in terms of tradables is α since the relative price of nontradables in terms of tradables is c_0^T. The present discounted value of a stream of α units of tradables is approximately α/r. Thus, if this value is larger than unity (the increase in tradable consumption afforded by a unit increase in debt in period 0), the planner will never choose to increase debt in period 0.

at all times. In the case in which $\alpha < r$, the trade-off is resolved in a more balanced fashion. The optimal capital control policy consists in reducing (but not eliminating) inefficient unemployment and distorts (although less strongly) the intertemporal allocation of consumption. As we will see shortly, the thrust of these findings carries over to richer economic environments.

VIII. Evidence on Downward Nominal Wage Rigidity and Estimates of γ

The central friction in the present theoretical framework is downward nominal wage rigidity, embodied in the parameter γ. There is abundant empirical evidence on downward nominal wage rigidity stemming mostly from developed countries.[8] In this section we present novel evidence from emerging countries and propose an empirical strategy for identifying the wage rigidity parameter γ. The strategy consists in observing the behavior of nominal wages during periods of rising unemployment and low inflation. We focus on episodes in which an economy undergoing a severe recession keeps the nominal exchange rate fixed. Two prominent examples are Argentina during the second half of the Convertibility Plan (1998–2001) and the periphery of Europe during the Great Recession of 2008.

Figure 6 displays the nominal exchange rate, subemployment (defined as the sum of unemployment and underemployment), nominal (peso) wages, and real (dollar) wages for Argentina during the period 1996–2006. The subperiod 1998–2001 is of particular interest because during that time the Argentine central bank was holding on to the currency peg in spite of the fact that the economy was undergoing a severe contraction and both unemployment and underemployment were in a steep ascent. In the context of a flexible-wage model, one would expect that the rise in unemployment would be associated with falling real wages. With the nominal exchange rate pegged, the fall in real wages must materialize through nominal wage deflation. However, during this period, the nominal hourly wage never fell. Indeed, it increased from 7.87 pesos in 1998 to 8.14 pesos in 2001. The present model predicts that with rising unemployment, the lower bound on nominal wages should be binding, and therefore, γ should equal the gross growth rate of nom-

[8] See, e.g., Gottschalk (2005) for the United States from 1986 to 1993; Barattieri, Basu, and Gottschalk (2010) for the United States from 1996 to 1999; Daly, Hobijn, and Lucking (2012) for the United States during the Great Recession of 2008; Eichengreen and Sachs (1985) for western Europe during the Great Depression of 1929; Holden and Wulfsberg (2008) for OECD countries; Fortin (1996) for Canada; Kuroda and Yamamoto (2003) for Japan; and Fehr and Goette (2005) for Switzerland. Kaur (2012) presents evidence from informal labor markets in rural India.

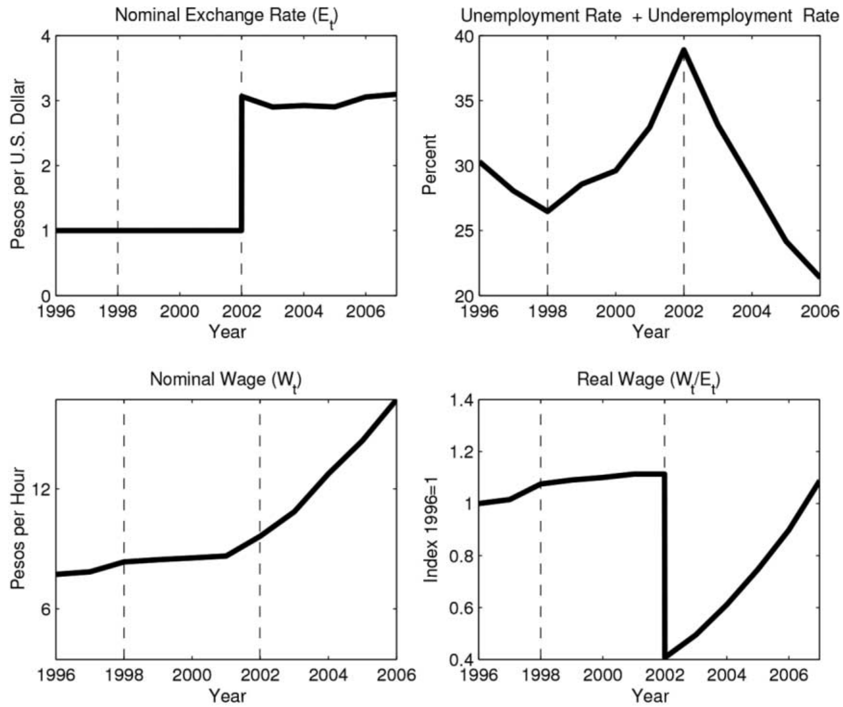

FIG. 6.—Nominal wages and unemployment in Argentina, 1996–2006. Own calculations based on nominal exchange rate and nominal wage data from the Bureau of Labor Statistics and subemployment data from Instituto Nacional de Estadistica y Censos de Argentina. The data are provided with the online materials of this paper.

inal wages. An estimate of the parameter γ can then be constructed as the average quarterly growth rate of nominal wages over the 3-year period considered, that is, $\gamma = (W_{2001}/W_{1998})^{1/12}$. This yields a value of γ of 1.0028.

In order for this estimate of γ to represent an appropriate measure of wage rigidity in the context of the theoretical model, it must be adjusted to account for the fact that our model abstracts from foreign inflation and long-run productivity growth. To carry out this adjustment, we use the growth rate of the US GDP deflator as a proxy for foreign inflation. Between 1998 and 2001, the US GDP deflator grew by 1.77 percent per year on average. We set the long-run growth rate in Argentina at 1.07 percent per year, to match the average growth rate of Argentine per capita real GDP over the period 1900–2005 reported in García-Cicco, Pancrazi, and Uribe (2010). The adjusted value of γ is then given by $1.0028/(1.0107 \times 1.0177)^{1/4} = 0.9958$. This value of γ means that real wages can fall frictionlessly by 1.7 percent per year.

We note additionally that the fact that Argentine real wages fell significantly and persistently after the devaluation of 2002 (bottom-right panel of fig. 6) suggests that the 1998–2001 period was one of censored wage deflation, which further strengthens the view that nominal wages suffer from downward inflexibility.

Finally, we note that during the 1998–2001 Argentine contraction, consumer prices, unlike nominal wages, did fall significantly. The consumer price index (CPI) rate of inflation was, on average, -0.86 percent per year over the period 1998–2001. It follows that real wages rose not only in dollar terms but also in terms of CPI units. Incidentally, this evidence provides some support for our assumption that downward nominal rigidities are less stringent for product prices than for factor prices.

The second episode from the emerging-market world that we use to infer the value of γ is the Great Recession of 2008 in the periphery of Europe. Table 1 presents an estimate of γ for 12 European economies that are either on the euro or pegging to the euro. The table shows the unemployment rate in 2008:Q1 and 2011:Q2. The starting point of this period corresponds to the beginning of the Great Recession in Europe according to the Centre for Economic Policy Research Euro Area Business Cycle Dating Committee. The 2008 crisis caused unemployment rates to rise sharply across all 12 countries. The table also displays the total growth of nominal hourly labor cost in manufacturing, construction, and services (including the public sector) over the 13-quarter period 2008:Q1–2011:Q2.[9] Despite the large surge in unemployment, nominal wages grew in most countries, and in those in which they fell, the decline was modest. The implied value of γ, shown in the last column of table 1, is given by the average growth rate of nominal wages over the period considered, that is, $\gamma = (W_{2011:Q2}/W_{2008:Q1})^{1/13}$. The estimated values of γ range from 0.996 for Lithuania to 1.028 for Bulgaria.

To adjust γ for foreign inflation, we use the fact that over the 13-quarter sample period considered in table 1, inflation in Germany was 3.6 percent, or about 0.3 percent per quarter. To adjust for long-run growth, we use the average growth rate of per capita output in the southern periphery of Europe of 1.2 percent per year or 0.3 percent per quarter.[10] Allowing for these effects suggests an adjusted estimate of γ in the interval [0.990, 1.022].

Taken together, the evidence examined in this section suggests that downward nominal wage rigidity is pervasive in emerging countries and that during low-inflation periods a conservative estimate of γ is

[9] The public sector is not included for Spain because of data limitations.

[10] This figure corresponds to the average growth rate of per capita real GDP in Greece, Spain, Portugal, and Italy over the period 1990–2011 according to the World Development Indicators.

TABLE 1
UNEMPLOYMENT, NOMINAL WAGES, AND γ: EVIDENCE FROM THE EURO ZONE

Country	Unemployment Rate		Wage Growth	Implied Value of γ
	2008:Q1 (%)	2011:Q2 (%)	$W_{2011:Q2}/W_{2008:Q2}$	
Bulgaria	6.1	11.3	43.3	1.028
Cyprus	3.8	6.9	10.7	1.008
Estonia	4.1	12.8	2.5	1.002
Greece	7.8	16.7	−2.3	.9982
Ireland	4.9	14.3	.5	1.0004
Italy	6.4	8.2	10.0	1.007
Lithuania	4.1	15.6	−5.1	.996
Latvia	6.1	16.2	−.6	.9995
Portugal	8.3	12.5	1.91	1.001
Spain	9.2	20.8	8.0	1.006
Slovenia	4.7	7.9	12.5	1.009
Slovakia	10.2	13.3	13.4	1.010

NOTE.—Own calculations are based on data from Eurostat. The variable W is an index of nominal average hourly labor cost in manufacturing, construction, and services. Unemployment is the economywide unemployment rate. The data are provided with the online materials of this paper.

0.99 at a quarterly frequency. This value implies that nominal wages can decline up to 4 percent per year.

IX. Quantitative Analysis

In this section we characterize quantitatively the behavior of the economy under the alternative policy arrangements analyzed theoretically in Sections III–VI.

A. Calibration

We calibrate the model at a quarterly frequency using data from Argentina as shown in table 2. We estimate a bivariate AR(1) process for the

TABLE 2
BASELINE CALIBRATION

Parameter	Value	Description
γ	.99	Degree of downward nominal wage rigidity
σ	5	Inverse of intertemporal elasticity of consumption
y^T	1	Steady-state tradable output
$\bar{h}$	1	Labor endowment
a	.26	Share of tradables
ξ	.44	Elasticity of substitution between tradables and nontradables
α	.75	Labor share in nontraded sector
β	.9375	Quarterly subjective discount factor

exogenous driving forces (y_t^T, r_t) by ordinary least squares using data over the period 1983:Q1 to 2001:Q4. The empirical measure of y_t^T is the cyclical component of Argentine GDP in agriculture, forestry, fishing, mining, and manufacturing at 1993 prices. We measure the country-specific real interest rate as the sum of the Emerging Market Bond Index + spread for Argentina and the 90-day US Treasury Bill rate, deflated using a measure of expected dollar inflation.[11] Online appendix E provides further details on the data sources. The estimated process is

$$\begin{bmatrix} \ln y_t^T \\ \ln \dfrac{1+r_t}{1+r} \end{bmatrix} = \begin{bmatrix} 0.7901 & -1.3570 \\ -0.0104 & 0.8638 \end{bmatrix} \begin{bmatrix} \ln y_{t-1}^T \\ \ln \dfrac{1+r_{t-1}}{1+r} \end{bmatrix} + \epsilon_t;$$
$$\epsilon_t \sim N\left(\varnothing, \begin{bmatrix} 0.0012346 & -0.0000776 \\ -0.0000776 & 0.0000401 \end{bmatrix}\right), \tag{34}$$

and $r = 0.0316$. According to these estimates, both $\ln y_t^T$ and r_t are highly volatile, with unconditional standard deviations of 12.2 percent and 1.7 percent per quarter, respectively. The unconditional contemporaneous correlation between $\ln y_t^T$ and r_t is high and negative at -0.86, implying that borrowing conditions for debtors tend to deteriorate at the wrong time, namely, when output is low. The estimated joint autoregressive process implies that both traded output and the real interest rate are persistent, with first-order autocorrelations of .95 and .93, respectively. The estimated value of the steady-state real interest rate is high at 3.16 percent per quarter, or 13.2 percent per year.

We set γ at 0.99, the lowest of the cross-country estimates reported in Section VIII. This value imposes the least amount of wage rigidity detected in the Argentine and European data. This value of γ means that nominal wages can fall by up to 4 percent per year. Online appendix G.4 considers the case of $\gamma = 0.98$, which allows nominal wages to fall by up to 8 percent per year.

We assume the constant relative risk aversion form $U(c) = (c^{1-\sigma} - 1)/(1-\sigma)$ for the period utility function, the constant elasticity of substitution form

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

for the aggregator function, and the isoelastic form $F(h) = h^\alpha$ for the production function of nontradables. Reinhart and Végh (1995) esti-

[11] The country-specific interest rate reflects the fact that, in general, each country borrows at a different interest rate. The country interest rate captures factors such as country-specific repayment risk. These idiosyncratic interest rate differentials are present even for countries that are part of a monetary union, such as the members of the euro zone.

mate the intertemporal elasticity of substitution to be 0.21 using Argentine quarterly data. We therefore set σ equal to 5. Online appendix G.3 considers a value of σ close to 2. We set $\bar{h}$ equal to unity. Then, if the steady-state trade balance to output ratio is small, as is the case in Argentina, the parameter a is approximately equal to the share of traded output in total output.[12] The share of traded output observed in Argentine data over the period 1980:Q1–2010:Q1 is 26 percent; hence we set $a = 0.26$. Using time-series data for Argentina over the period 1993:Q1–2001:Q3, González Rozada et al. (2004) estimate the elasticity of substitution between traded and nontraded consumption, ξ, to be 0.44. This estimate is consistent with the cross-country estimates of Stockman and Tesar (1995). These authors include in their estimation both developed and developing countries. Restricting the sample to include only developing countries yields a value of ξ of 0.43 (see Akinci 2011). Following Uribe's (1997) evidence on the size of the labor share in the nontraded sector in Argentina, we set α equal to 0.75.

We set $\bar{d}$ at the natural debt limit, which we define as the level of external debt that can be supported with zero tradable consumption when the household perpetually receives the lowest possible realization of tradable endowment, $y^{T^{\min}}$, and faces the highest possible realization of the interest rate, $r^{\max}$. Formally, $\bar{d} \equiv y^{T^{\min}}(1 + r^{\max})/r^{\max}$, which in the present calibration equals 8.34.

Finally, we set β to match an average foreign-debt-to-output ratio of 26 percent per year, a value in line with that reported for Argentina over our calibration period by Lane and Milesi-Ferretti (2007). The calibrated value of β is small relative to those typically used to calibrate closed-economy models or open-economy models with a stationarity-inducing feature as described in Schmitt-Grohé and Uribe (2003). But low values of β are more common in open-economy models that do not include a stationarity-inducing device.

B. *Approximating Equilibrium Dynamics*

Here we sketch the numerical solution methods we employ to approximate the equilibrium dynamics under the three policy arrangements we consider, namely, in ascending order of computational complexity, the optimal exchange rate policy, a currency peg with optimal capital controls, and a currency peg with free capital mobility.

Under all three policy arrangements, the approximation involves discretizing the state space. We discretize the exogenous AR(1) process

[12] The parameter a is approximately equal to the share of tradable output in total output even though $\xi \neq 1$ because, if the trade balance is near zero, traded output is near unity, and hours are close to $\bar{h} = 1$, we have that $c^N = y^N \approx c^T \approx y^T \approx 1$ and $p \approx (1 - a)/a$, which implies that $y^T/(y^T + py^N) \approx a$.

(34) using 21 equally spaced points for $\ln y_t^T$ in the interval ±0.3858 and 11 equally spaced points for $\ln(1+r_t)/(1+r)$ in the interval ±0.0539.[13] The transition probability matrix of the exogenous driving process is therefore of size 231×231.[14] To compute this matrix, we follow the algorithm described in Schmitt-Grohé and Uribe (2009). The resulting transition probability matrix captures well the covariance matrices of order 0 and 1.

To discretize the endogenous state d_t, we use 501 equally spaced points. We fix the upper bound of the debt grid at 8, which is close to $\bar{d} = 8.34$, and the lower bound at -5.

When the exchange rate policy takes the form of a currency peg (whether combined with free capital mobility or with capital controls), a second endogenous state emerges, namely, past real wages, w_{t-1}. We discretize this state using a grid of 500 equally spaced points for the logarithm of w_{t-1}. We set the lowest grid value of w_{t-1} at 0.5 and the highest at 5.3.

The equilibrium dynamics under the optimal exchange rate policy are obtained from the solution to the value function problem given by the functional equation (23) and the constraints (8), (10), and (11). We numerically approximate this solution by applying the method of value function iteration over a discretized state space. Under the optimal exchange rate policy, the state of the economy in period $t \geq 0$ is the triplet $\{y_t^T, r_t, d_t\}$.

The equilibrium dynamics under a currency peg with the optimal capital control policy can be approximated by solving the functional equation (32) subject to (10), (11), (16), (18), and (30). Approximating the equilibrium dynamics in this environment is more demanding than doing so under the optimal exchange rate policy because the former problem includes an additional state variable, namely, w_{t-1}. We numerically approximate the equilibrium dynamics 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 quadruplet $\{y_t^T, r_t, d_t, w_{t-1}\}$.

The task of approximating the equilibrium dynamics becomes even more challenging under a currency peg with free capital mobility. As in the case of a currency peg with optimal capital controls, there are four state variables, y_t^T, r_t, d_t, and w_{t-1}. However, under a currency peg with free capital mobility, aggregate dynamics cannot be cast in terms of a Bellman equation without introducing additional state variables, such as the individual level of debt, which households perceive as distinct from its aggregate counterpart. We therefore approximate the solution by

[13] The lengths of these intervals are $2 \times \sqrt{10}$ times the standard deviation of each variable.

[14] Because some pairs (y_t^T, r_t) occur with probability zero, the transition probability matrix can be reduced to one of dimension 145×145.

Euler equation iteration over a discretized version of the state space $(y_t^T, r_t, d_t, w_{t-1})$. Online appendix F describes our numerical algorithm in more detail. Matlab codes are provided with the online materials of this paper.

C. *Boom-Bust Cycles*

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. This definition is motivated by the contraction in aggregate activity observed in Argentina in 2001. 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.

The top two panels of figure 7 display the dynamics of the two exogenous driving forces, tradable output and the country interest rate. Because our estimate of the exogenous driving forces features a high negative correlation between traded output and the country interest rate, a boom-bust episode can also be interpreted as one in which the interest rate falls one standard deviation below mean over a period of 10 quarters and then rises to one standard deviation above mean in the following 10 quarters.

The middle and bottom panels of the figure depict the model's predictions during the boom-bust cycle. Solid lines correspond to the economy with a currency peg and free capital mobility, broken lines to the economy with a currency peg and optimal capital controls, and dotted lines to the economy with the optimal exchange rate policy.

The middle-left panel of the figure shows that the optimal capital control policy is prudential. Capital controls increase significantly during the expansionary phase of the cycle, from about 2 percent at the beginning of the episode to 6 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 tradable consumption (see the bottom-right panel). Under a peg with free capital mobility, during the boom, tradable consumption increases significantly more than under the optimal capital control policy. In the contractionary phase, the fiscal authority incentivates spending in tradables 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 severe cuts in tradable consumption, supports this type of expenditure. That is, the capital control policy stabilizes the absorption of tradable

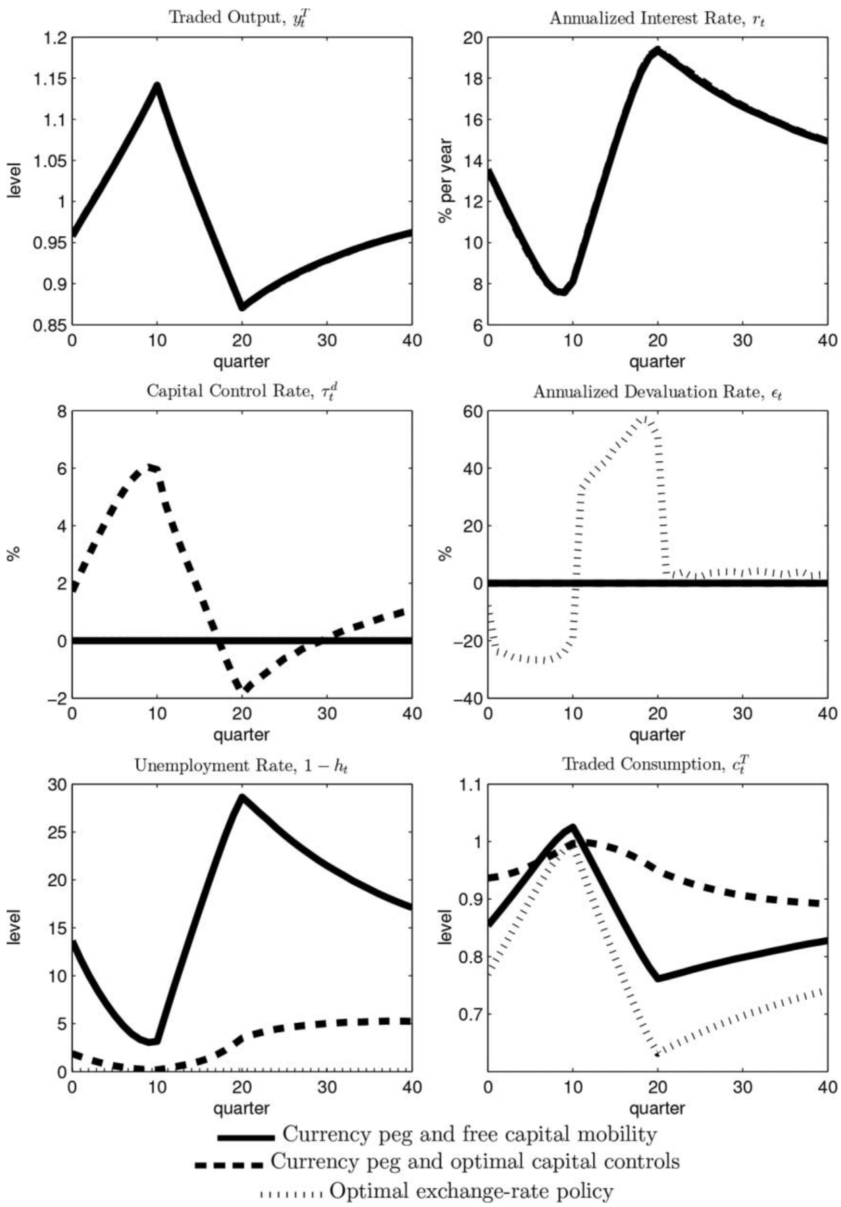

FIG. 7.—Boom-bust dynamics

goods 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 trade surpluses during crises.

Because unemployment depends directly on 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. As can be seen from the bottom-left panel of figure 7, in the peg economy without 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 trade-off between distorting the intertemporal allocation of tradable consumption and reducing unemployment is overwhelmingly resolved in favor of the latter.

Indeed, the rate of unemployment in the peg economy with optimal capital controls is much closer to the unemployment rate under the optimal exchange rate policy (equal to zero at all times) than to the unemployment rate in the peg economy with free capital mobility. However, the means by which the policy maker achieves low unemployment in the peg economy with optimal capital controls and in the optimal exchange rate policy economy are quite different. In the optimal capital control economy, lower unemployment is the consequence of stabilizing traded absorption (i.e., stabilizing the demand schedule in fig. 4). By contrast, under the optimal exchange rate policy, low unemployment is achieved through a series of large currency devaluations (middle-right panel of fig. 7) that lower the labor cost in the nontraded sector during crises (i.e., by shifts in the supply schedule in fig. 4).

D. *Level and Volatility Effects of Optimal Capital Controls*

Table 3 displays unconditional first and second moments of macroeconomic indicators of interest. 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 an average of 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 IX.E.

Table 3 also shows that the tax on debt is highly volatile, with a standard deviation of 5.2 percentage points per quarter. The main payoff

TABLE 3

OPTIMAL CAPITAL CONTROLS: LEVEL AND VOLATILITY EFFECTS

		Mean			Standard Deviation		
Variable	Symbol	Optimal Exchange Rate Policy	Peg with Optimal Capital Controls	Peg with No Capital Controls	Optimal Exchange Rate Policy	Peg with Optimal Capital Controls	Peg with No Capital Controls
Capital control rate	τ_t^d	0	2.4	0	0	5.2	0
Unemployment rate	$\bar{h} - h_t$	0	3.1	13.5	0	7.6	11.7
Consumption	c_t	.93	.97	.89	.08	.08	.10
Trade balance	$y_t^T - c_t^T$	.18	.05	.11	.10	.12	.07
Real wage	W_t/E_t	1.5	2.1	2.3	.8	.6	.7
Traded output	y_t^T	1.0	1.0	1.0	.1	.1	.1
Interest rate	r_t	13.2	13.2	13.2	7.4	7.4	7.4
External debt	d_t	5.8	.9	3.4	.4	2.3	.7
Debt-to-output ratio	$d_t/4(y^T + p_t c_t^N)$	57.9	11.2	26.0	28.6	22.1	12.6

NOTE.—The variables τ_t^d, $\bar{h} - h_t$, and $d_t/4(y_t^T + p_t c_t^N)$ are expressed in percents; 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.

of imposing cyclical capital controls is a significant reduction in the average rate of unemployment from 13.5 percent under free capital mobility to 3.1 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 the average level of unemployment follows from the fact that consumption of tradables plays the role of a shifter of the demand for nontradables (see fig. 3). 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 .54 and the correlation between the interest rate r_t and τ_t^d is $-.58$. Indeed, 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 strongly negatively correlated with the latter.

Table 3 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 surprising because downward wage rigidity is the sole friction in the present model and because unemployment behaves markedly differently in the peg economy with free capital mobility and the peg economy with optimal capital controls. A reason why the unconditional moments of real wages are little affected by capital controls 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 under free capital mobility and under optimal capital controls 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 affected by capital controls.

E. *Peg-Induced Overborrowing*

Table 3 shows that the average level of external debt in the peg economy with free capital mobility is more than three times higher than it is in the peg economy with optimal capital controls (3.4 vs. 0.9). This prediction of the model is also evident from figure 8, which shows the unconditional distribution of external debt in the economy with a fixed exchange rate and free capital mobility (solid line) and in the economy with a fixed exchange rate and optimal capital controls (broken 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 the peg economy with free capital mobility accumulates inefficiently large amounts of external debt relative to the peg economy with optimal capital controls. In other words, conditional on being on a fixed exchange rate regime, economies with free capital mobility overborrow.

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 external debt position that is significantly more volatile than the one associated with free capital mobility. As shown in table 3, the standard deviation of external debt is 2.3 under optimal capital controls but only 0.7 under free capital mobility. Similarly, figure 8 shows that the distribution of external debt is significantly

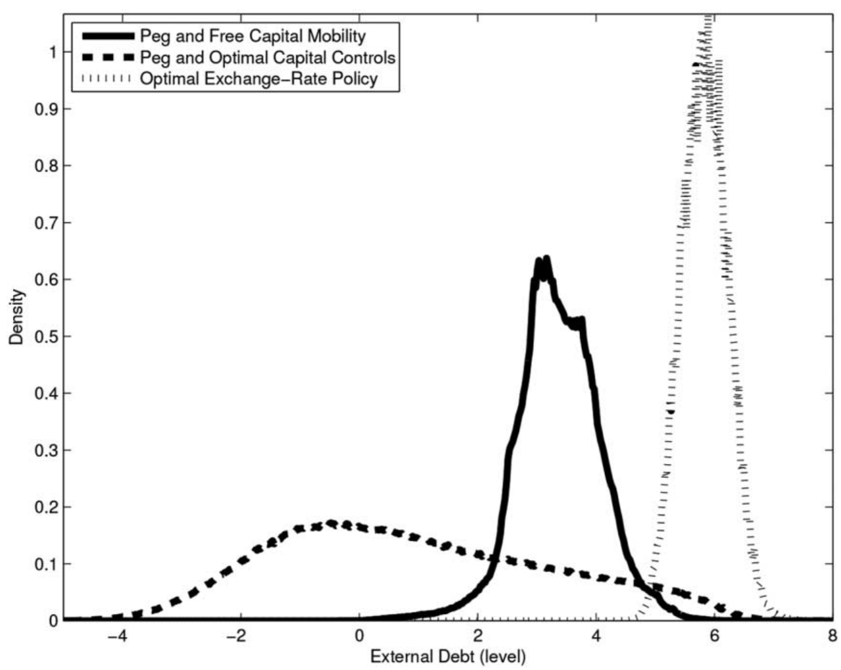

FIG. 8.—The distribution of external debt

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 than it does in the economy with free capital mobility.

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 8, the net external debt has a much more dispersed distribution under optimal capital controls than under free capital mobility.

Figure 8 shows that the distribution of net external debt under the optimal exchange rate policy (dotted line) has a higher mean and is much less dispersed than under a currency peg with optimal capital controls. This difference highlights the fact that the two policies achieve reductions in unemployment (relative to a currency peg with free capital mobility) through very different means. Under the optimal exchange rate policy, the government eliminates unemployment via devaluations that shift the supply of nontradables to offset variations in the demand for nontradables brought about by fluctuations in the desired consumption of tradables. In this way, the policy maker achieves two goals, full employment and an efficient allocation of tradable consumption over time. Under a currency peg with optimal capital controls, the policy maker cannot induce shifts in the supply of nontradables, since its hands are tied by the currency peg and the presence of downward nominal wage rigidity. Instead, the government reduces unemployment by minimizing shifts in the demand for nontradables. To this end, the government levies capital controls to stabilize the desired demand for tradable consumption, which is the key shifter of the demand schedule for nontradables. In turn, as explained above, a smooth path for tradable consumption can be supported only by large swings in the country's external debt position, which by necessity must be centered further away from the natural debt limit than it would be if tradable consumption were allocated optimally.

Finally, it is of interest to point out that the optimal capital control policy characterized here is complementary to the one that emerges in models of overborrowing due to collateral constraints (e.g., Korinek 2010; Bianchi 2011). In this class of models, households' ability to borrow is increasing in the value of output in terms of tradables. In turn, the value of output in terms of tradables is increasing in the relative price of nontradables. This relative price is endogenous to the model but exogenous to the household, which creates a pecuniary externality. The government understands that in equilibrium the relative price of nontradables is increasing in the absorption of tradables. Consequently, to induce a more relaxed collateral constraint on average, the government implements a policy that raises the average consumption of traded goods. To support higher average consumption of tradables, the economy must hold a lower average stock of external debt. This is achieved through capital controls. Thus, this literature shares two characteristics with the present model, namely, an externality that leads to overborrowing and positive average capital controls as a second-best remedy. The key difference, of course, resides in the nature of the externality, financial frictions in one case and downward wage rigidity in the other.

F. *Welfare Costs of Free Capital Mobility under a Currency Peg*

We have established that in the peg 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.

Define the welfare cost of a currency peg under free capital mobility conditional on state $s_t \equiv \{y_t^T, r_t, d_t, w_{t-1}\}$, denoted $\lambda^f(s_t)$, as the percentage increase in the lifetime consumption stream required by an individual living in the economy with a currency peg and free capital mobility in state s_t to be as well off as an individual living in an economy with the optimal exchange rate policy. Formally, $\lambda^f(s_t)$ solves

$$\mathbb{E}\left\{\sum_{j=0}^{\infty}\beta^j U\left(c_{t+j}^f\left(1+\frac{\lambda^f(s_t)}{100}\right)\right)\middle| s_t\right\} = v^o(y_t^T, r_t, d_t),$$

where c_t^f denotes consumption in the economy with a peg and free capital mobility and, as defined earlier, $v^o(y_t^T, r_t, d_t)$ denotes the value function in the economy with the optimal exchange rate policy in state (y_t^T, r_t, d_t). Because the state vector s_t is stochastic, the conditional welfare cost measure, $\lambda^f(s_t)$, is itself stochastic. We report the mean of $\lambda^f(s_t)$ over the distribution of s_t in the peg economy with free capital mobility. Formally, let $\pi^f(s_t)$ denote the unconditional probability of s_t under a peg with free capital mobility. Then

$$\lambda^f = \sum_{s_t}\pi^f(s_t)\lambda^f(s_t). \tag{35}$$

Similarly, the welfare cost of a currency peg under the optimal capital control policy conditional on state s_t, denoted $\lambda^c(s_t)$, is defined as the permanent percentage increase in the lifetime consumption stream required by an individual living in the economy with a currency peg and optimal capital controls in state s_t to be as well off as an individual living in the economy with the optimal exchange rate policy. That is, $\lambda^c(s_t)$ is implicitly given by

$$\mathbb{E}\left\{\sum_{j=0}^{\infty}\beta^j U\left(c_{t+j}^c\left(1+\frac{\lambda^c(s_t)}{100}\right)\right)\middle| s_t\right\} = v^o(y_t^T, r_t, d_t),$$

where c_t^c denotes consumption in the economy with a peg and optimal capital controls. Letting $\pi^c(s_t)$ denote the unconditional probability of s_t under a peg with optimal capital controls, we have that the expected value of the welfare cost of a peg under the optimal capital control policy is given by

$$\lambda^c = \sum_{s_t}\pi^c(s_t)\lambda^c(s_t). \tag{36}$$

Recalling that the optimal exchange rate policy achieves the Pareto-optimal allocation, one can interpret λ^f as the distance, in welfare terms, between the first-best allocation and the allocation induced by a currency peg with free capital mobility. Similarly, λ^c can be interpreted as the distance between the first-best allocation and the one induced by a currency peg coupled with Ramsey-optimal capital controls.

Table 4 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 11.6 percent in consumption every period to be indifferent between living under a peg with free capital mobility and living in an economy with the optimal exchange rate policy.

The optimal capital control policy greatly reduces the pains of currency pegs. Households living in an economy with a currency peg and optimal capital controls require a 3.7 percent increase in consumption each period to be as well off as living in the economy with the optimal exchange rate policy. The welfare gain of moving from a peg, with or without optimal capital controls, to the optimal exchange rate policy has three components: One is a reduction in unemployment, which translates into higher production and consumption of nontradables. This benefit is larger for the peg economy with free capital mobility. The second component is related to transitional dynamics along which households liquidate precautionary savings through higher-than-average consumption of tradables. This effect can be seen from figure 8, showing that the average level of external debt is higher under the optimal exchange rate policy than under

TABLE 4
THE COSTS OF CURRENCY PEGS

	Welfare Cost		Unemployment Rate	
	Peg with No Capital Controls	Peg with Optimal Capital Controls	Peg with No Capital Controls	Peg with Optimal Capital Controls
Economy	λ^f	λ^c	$100 \times \mathbb{E}[1 - (h_t/\bar{h})]$	
1. Baseline	11.6	3.7	13.5	3.1
2. Production in traded sector	10.1	5.0	7.8	1.9
3. Greece	17.6	6.0	15.3	3.7
4. $\sigma = 1/\xi = 2.27$ and $\beta = .962$	8.4	.6	12.4	.5
a. Less wage rigidity ($\gamma = .98$)	6.2	.4	9.5	.4
b. Endogenous labor supply ($\delta = .5$)	19.0	.8	33.5	1.3
c. Endogenous labor supply ($\delta = .75$)	9.3	.6	33.5	1.8
d. Endogenous labor supply ($\delta = 1$)	2.1	.3	33.5	8.4

NOTE.—Welfare costs are relative to the optimal exchange rate policy (or first-best allocation) and are expressed in percent of consumption per period (see expressions [35] and [36]). Unemployment rates are expressed in percent. For details see online app. G.

either of the two peg arrangements. The reduction in savings is greater for the peg economy with optimal capital controls. The third component is a lower long-run level of tradable consumption under the optimal exchange rate policy. This component represents a cost and is higher under optimal capital controls than under free capital mobility. Overall, the welfare gains are dominated by the reduction in unemployment.

A relevant question from a policy perspective is what are the welfare gains for a pegging economy with free capital mobility to adopt optimal capital controls. One might be tempted to conclude that the answer is $\lambda^f - \lambda^c$, or 7.9 percent of consumption per period. But this computation would fail to correctly take into account the transitional debt dynamics involved in moving from free capital mobility to optimal capital controls. As can be seen from figure 8, moving from a peg economy with free capital mobility to a peg with optimal capital controls requires reducing the average level of external debt. This deleveraging is costly, since it implies a temporarily lower-than-average level of consumption of tradables. This sacrifice is painful by itself, but it also causes unemployment to be higher along the transition (recall that consumption of tradables is a shifter of the demand for nontradables). In the long run the economy with optimal capital controls will enjoy a higher average level of tradable consumption than the economy with free capital mobility. In sum, moving from free capital mobility to optimal capital controls has the benefits of lower long-run unemployment (13.5 vs. 3.1 percent), higher long-run consumption of tradables (6.9 percent higher), but a transitional cost associated with debt deleveraging. Of course, by definition, there must be net gains from moving from free capital mobility to optimal capital controls. In our economy these gains turn out to be 2.2 percent of consumption per period.[15] This is a large number as welfare costs go in business cycle analysis but is not as high as the naive measure $\lambda^f - \lambda^c$.

Our finding of large welfare costs of currency pegs (with or without capital controls) stands in stark contrast to a large body of work, pioneered by Lucas (1987), suggesting that the costs of business cycles (not just of suboptimal monetary policy) are small. Lucas's approach to computing the welfare costs of business cycles abstracts from two features that are central determinants of welfare costs in our model,

[15] Formally, the welfare gain of switching from a peg with free capital mobility to a peg with optimal capital controls, denoted $\lambda^{f\to c}(s_t)$, is given by

$$\lambda^{f\to c} = \sum_{s_t} \pi^f(s_t)\lambda^{f\to c}(s_t),$$

where $\lambda^{f\to c}(s_t)$ is implicitly given by

$$\mathbb{E}\left\{\sum_{j=0}^{\infty}\beta^j U\left(c^f_{t+j}\left(1+\frac{\lambda^{f\to c}(s_t)}{100}\right)\right)\middle|\, s_t\right\} = \mathbb{E}\left\{\sum_{j=0}^{\infty}\beta^j U(c^c_{t+j})\,\middle|\, s_t\right\}.$$

namely, the effect of volatility on mean unemployment and transitional dynamics. The lack of connection between volatility and means within Lucas's approach can be seen by noticing that it consists in first removing a trend from a consumption time series and then evaluating a second-order approximation of welfare using observed deviations of consumption from trend. Under this approach, the welfare cost of business cycles depends only on the volatility of the cyclical component of consumption. Implicit in this methodology is the assumption that the trend is unaffected by policy. In our model, however, suboptimal monetary policy creates an endogenous connection between the amplitude of the business cycle and the average rate of unemployment. In turn, through its effect on the average level of unemployment, suboptimal exchange rate policy has a significant effect on the average level of consumption of nontradables (recall that nontradables are produced with labor). It follows that applying Lucas's methodology to data stemming from our model would overlook the effects of policy on mean consumption and therefore would result in spuriously low welfare costs.

The importance of transitional dynamics for welfare can be seen by comparing the mean and standard deviation of consumption in the economy with a peg and optimal capital controls and the economy with optimal exchange rate policy. The welfare cost of pegs with optimal capital controls relative to the optimal exchange rate policy is 3.7 percent of consumption per period even though consumption under the former policy has a higher mean (0.97 vs. 0.93) and the same volatility (0.08) as under the latter. The reason why the peg with optimal capital controls is welfare dominated by the economy with the optimal exchange rate policy is that the former is associated with an inefficiently low level of external debt. As a result, an economy that switches from a peg with optimal capital controls to the optimal exchange rate policy enjoys a transition with high absorption of tradables as it accumulates external debt.

Because our model is stylized, we interpret the present welfare evaluation as suggestive. The sensitivity analysis presented in online appendix G and summarized in table 4 provides some more support for the size of the welfare losses reported here. In particular, it shows that the main findings are robust to allowing for production in the traded sector, estimating the driving process using data from Greece, considering a higher intertemporal elasticity of substitution (or lower value of σ), allowing for more wage flexibility, and introducing endogenous labor supply.

X. Conclusion

We document the presence of downward nominal wage rigidity in low-inflation emerging economies with fixed nominal exchange rates. We estimate that even in the context of massive unemployment, nominal hourly wages fail to fall at a rate larger than 1 percent per quarter. With this motivation in mind, we develop a dynamic stochastic model of an open economy with downward nominal wage rigidity and analyze its adjustment to large external shocks.

A key insight of the model is that the combination of downward nominal wage rigidity and a fixed exchange rate gives rise to a negative externality. The nature of the externality is that 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 falls back to its trend path, wages fail to decline 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 externality thus leads to overborrowing during booms and to excessive unemployment during downturns.

We show that without policy intervention, currency pegs can be painful for economies that are subject to large external shocks. For example, a calibrated version of our model predicts that an external shock, defined as a two standard deviation collapse in the terms of trade and a two standard deviation increase in the country interest rate, causes an increase in unemployment of more than 20 percent of the labor force. This figure is consistent with the unemployment rates observed in the aftermath of recent large contractions in emerging-market economies that followed a fixed exchange rate regime, including Argentina 1998–2001 and the periphery of the European Union after 2008.

One policy option to address the unemployment problem is to abandon the currency peg in favor of the optimal exchange rate policy. We show that the optimal exchange rate policy calls for large devaluations in response to large external shocks. These devaluations reduce the real value of wages, allowing the labor market to clear. In the calibrated model, boom-bust cycles of the type observed in Argentina in 1998–2001 and in the periphery of Europe after 2008 call for devaluations of about 100 percent.

We demonstrate that an alternative to devaluation is the optimal fiscal policy. For example, optimal wage subsidies at the firm level financed by income taxes at the household level can fully undo the distortions created by the combination of downward nominal wage rigidity and a currency peg and therefore can bring about the Pareto-optimal allocation. We argue, however, that such policies might not be practical to implement in a political environment focused on fiscal austerity such as the one prevailing in Europe after 2008. This motivates our analysis of optimal capital control policy, broadly interpreted as regulations of cross-border financial flows, as an alternative way to address the aforementioned negative externality.

We show 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. 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 to the nontraded sector causing unemployment. Capital controls, although they represent only a second-best policy, can go a long way toward restoring full employment in fixed exchange rate economies. Under our baseline calibration, the average rate of unemployment falls from 13.5 to 3.1 percent when the currency peg is coupled with optimal capital controls.

These results suggest that when labor markets suffer from downward nominal wage rigidity and the exchange rate is fixed, countercyclical capital controls can be an effective instrument for macroeconomic stabilization.

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