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Stephanie Schmitt-Grohe
Martin Uribe

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ABSTRACT

This paper quantifies the costs of adhering to a fixed-exchange-rate arrangement, such as a currency union, for emerging economies. To this end it develops a novel dynamic stochastic disequilibrium model of a small open economy with monetary nonneutrality due to downward nominal wage rigidity. In the model, a negative external shock causes persistent unemployment because the fixed exchange rate and downward wage rigidity stand in the way of real depreciation. In these circumstances, optimal exchange-rate policy calls for large devaluations. In a calibrated version of the model, a large contraction, defined as a two-standard-deviation decline in tradable output causes the unemployment rate to rise by more than 20 percentage points under a peg. The required devaluation under the optimal exchange-rate policy is more than 50 percent. The median welfare cost of a currency peg is shown to be enormous, about 10 percent of lifetime consumption. Adhering to a fixed exchange-rate arrangement is found to be more costly when initial fundamentals are characterized by high past wages, large external debt, high country premia, or unfavorable terms of trade.

Stephanie Schmitt-Grohe
Department of Economics
Columbia University
New York, NY 10027
and NBER
stephanie.schmittgrohe@columbia.edu

Martin Uribe
Department of Economics
Columbia University
International Affairs Building
New York, NY 10027
and NBER
martin.uribe@columbia.edu

1 Introduction

Fixed-exchange-rate arrangements are easy to adopt but difficult to maintain. Countries can find themselves confined to a currency peg in a number of ways. For instance, a country could have adopted a currency peg as a way to stop high or hyperinflation in a fast and nontraumatic way. A classical example is the Argentine Convertibility Law of April 1991, which, by mandating a one-to-one exchange rate between the Argentine peso and the U.S. dollar, painlessly eliminated hyperinflation in less than a year. Another route by which countries arrive at a currency peg is the joining of a monetary union. Recent examples include emerging countries in the periphery of the European Union, such as Ireland, Portugal, Greece, and a number of small eastern European countries that joined the Eurozone. Most of these countries experienced an initial transition into the Euro characterized by low inflation, low interest rates, and economic expansion.

The Achilles' heel of currency pegs is, however, that they hinder the efficient adjustment of the economy to negative external shocks, such as drops in the terms of trade or hikes in the country interest-rate premium. The reason is that such shocks produce a contraction in aggregate demand that requires a decrease in the relative price of nontradables, that is, a real depreciation of the domestic currency, in order to bring about an expenditure switch away from tradables and toward nontradables. In turn, the required real depreciation may come about via a nominal devaluation of the domestic currency or via a fall in nominal prices or both. The currency peg rules out a devaluation. Thus, the only way the necessary real depreciation can occur is through a decline in the nominal price of nontradables. However, if nominal prices, especially factor prices, are downwardly rigid, the real depreciation will take place only slowly, causing recession and unemployment along the way.

This paper investigates how costly it is to maintain a currency peg, in terms of unemployment and welfare, for an emerging economy facing large external shocks. To this end, the paper embeds downward nominal wage rigidity into a dynamic, stochastic, disequilibrium (DSD) model of a small open economy with traded and nontraded goods. The key feature that distinguishes our theoretical framework from existing models of nominal wage rigidity is that in our formulation wage rigidity gives rise to occasionally binding constraints that may prevent the real wage from falling to its efficient level. In turn, these constraints, when binding, produce involuntary unemployment. A second distinguishing feature of our model of downward wage rigidity is that it does not rely on the assumption of imperfect competition in product or factor markets.

We show that in our DSD model, the optimal exchange-rate policy takes the form of a time-varying rate of devaluation that allows the real wage to equal the efficient real wage at all times. Under the optimal exchange-rate policy, the central bank devalues the nominal currency in periods in which the full-employment real wage rate experiences a sizable decline. These are typically periods in which the economy suffers negative external shocks. In all other periods, keeping the nominal exchange-rate constant is consistent with full employment. It follows that under the optimal policy, the devaluation rate may be positive on average. As a consequence, the optimal rate of inflation can also be positive on average. In this case, our DSD model captures Olivera's (1960, 1964) concept of structural inflation. This result is important in light of the difficulties that the existing theoretical literature on the optimal rate of inflation has faced in rationalizing observed inflation targets of 2 percent or higher (see Schmitt-Grohé and Uribe, 2010, for a survey).

The model is driven by stochastic disturbances to the traded endowment and to the country interest-rate premium. We estimate this process using Argentine data. We then feed this driving process into a calibrated version of the model and simulate the dynamics triggered by a large negative shock. We define a large shock as a situation in which tradable output falls below trend by at least two standard deviations over a period of two and a half years. According to our estimates, shocks of this magnitude occur once every 66 years. We compare the dynamics of the economy during the crisis under a currency peg and under the optimal exchange-rate policy. Under the peg, the rate of unemployment rises by more than 20 percentage points. Even though tradable goods are scarce and there is open unemployment in the nontradable sector, the relative price of nontradables (the real exchange rate) fails to fall because of the combination of downward nominal wage rigidity and a fixed exchange rate. By contrast, under the optimal exchange-rate policy the government devalues the currency by more than 50 percent. As a consequence, the real wage falls significantly and so does the relative price of nontradables. The adjustment of the real wage induced by the devaluation enables the economy to operate at full employment.

We measure the cost of maintaining a currency peg as the difference between the level of welfare enjoyed by households under a currency peg and the level of welfare associated with the optimal exchange-rate policy. We find that the median welfare cost of living under a currency peg is enormous, about 10 percent of lifetime consumption. And weak fundamentals can bring this figure even higher. In particular, high levels of past wages, a large initial stock of external debt, a high country premium, and unfavorable terms of trade all exacerbate the welfare loss of living under a peg.

An important implication of our disequilibrium model is that the exchange-rate regime has a significant impact on the long-run distribution of external debt. Specifically, we find that under a currency peg the probability distribution of external debt has a smaller mean but a larger support than the debt distribution associated with the optimal exchange-rate regime.

The reason for this difference is that under a currency peg the relative price of nontradables fails to signal the scarcity of tradable goods and the relative abundance of nontradable goods during a negative external shock. Because the relative price of nontradables stays inefficiently high, households overconsume traded goods and underconsume nontraded goods, leading to an inefficient overaccumulation of external debt during crises. In turn, the wider support of the debt distribution forces households to maintain on average less debt to avoid hitting the natural debt limit.

The remainder of the paper is organized in seven sections. Section 2 develops a novel disequilibrium model of unemployment due to downward wage rigidities with competitive labor markets and embeds it into a dynamic stochastic small open economy framework. Section 3 analyzes optimal exchange rate policy. Section 4 characterizes the response of the economy to a large negative external shock when exchange rate policy is optimal. Section 5 considers the response to the same shock in the case that the exchange rate is fixed. This section also analyzes how the exchange-rate policy affects the long-run distribution of external debt. Section 6 calculates the welfare benefits of switching from a currency peg to the optimal exchange rate policy. Section 7 studies the robustness of our findings to variations in the values taken by the calibrated parameters. Finally, section 8 concludes.

2 A Dynamic Stochastic Disequilibrium Model

In this section, we develop a novel model of a small open economy in which nominal wages are downwardly rigid. In the model, the labor market is perfectly competitive. As a result, even though all participants understand that wages are nominally rigid, they do not act strategically in their pricing behavior. Instead, workers and firms take factor prices as given. The model features a traded and a nontraded sector and aggregate fluctuations are driven by stochastic movements in the value of tradable output and in the country-specific interest rate.

2.1 Households

The economy is populated by a large number of infinitely-lived 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 utility index assumed to be increasing and strictly concave, $\beta \in (0,1)$ is a subjective discount factor, and $\mathbb{E}_t$ is the expectations operator conditional on information available in period t. Consumption is assumed to be a composite good made of tradable and nontradable goods via the aggregation process

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

where c_t^T denotes consumption of tradables, c_t^N denotes consumption of nontradables, and A denotes an aggregator function assumed to be homogeneous of degree one, increasing, concave, and to satisfy the Inada conditions. These assumptions imply that consumption of tradables and nontradables are normal goods.

Households are assumed to be endowed with an exogenous and stochastic amount of tradable goods, y_t^T, and a constant number of hours, $\bar{h}$, which they supply inelastically to the labor market. Because of the presence of nominal wage rigidities in the labor market, households will in general only be able to work $h_t \leq \bar{h}$ hours each period. Households take h_t as exogenously determined. Households also receive profits from the ownership of firms, denoted ϕ_t and expressed in terms of tradables. Households have access to an internationally traded risk-free pure discount bond that pays the country-specific interest rate in terms of tradable goods r_t when held between periods t and $t+1$. The household's sequential budget constraint in period t is then given by

$$c_t^T + p_t c_t^N + d_t \leq y_t^T + w_t h_t + \frac{d_{t+1}}{1+r_t} + \phi_t, \tag{3}$$

where p_t denotes the relative price of nontradables in terms of tradables in period t, d_{t+1} is the amount of debt assumed in period t and maturing in period $t+1$, and w_t denotes the real wage rate in terms of tradables in period t. Households are subject to a no-Ponzi game constraint taking the form of the following debt limit

$$d_{t+1} \leq \bar{d}, \quad \text{for } t \geq 0, \tag{4}$$

where $\bar{d}$ is less than the natural debt limit.

The optimization problem of the household consists in choosing contingent plans c_t, c_t^T, c_t^N, and d_{t+1} to maximize (1) subject to the aggregation technology (2), the sequential budget constraint (3), and the borrowing limit (4). Letting λ_t and μ_t denote the Lagrange multipliers associated with (3) and (4), respectively, the optimality conditions associated with this dynamic maximization problem are (2), (3) holding with equality, (4), and

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

$$\lambda_t = U'(c_t) A_1(c_t^T, c_t^N), \tag{6}$$

$$\frac{\lambda_t}{1+r_t} = \beta \mathbb{E}_t \lambda_{t+1} + \mu_t \tag{7}$$

$$\mu_t \geq 0 \tag{8}$$

$$\mu_t(d_{t+1} - \bar{d}) = 0, \tag{9}$$

where A_i denotes the partial derivative of A with respect to its i-th argument. Intuitively, optimality condition (5) states that an increase in the relative price of nontradables induces households to engage in expenditure switching by consuming relatively more tradables and less nontradables. The maintained assumptions on the form of the aggregator function A guarantee that the left-hand side of this expression is an increasing function of the ratio c_t^T/c_t^N. Optimality condition (7) equates the marginal benefits and the marginal costs of borrowing $1/(1+r_t)$ units of tradables in period t. The left-hand side of this expression indicates the marginal utility of an additional $1/(1+r_t)$ units of tradables consumed in period t. The right-hand side presents the marginal costs of borrowing $1/(1+r_t)$ units of tradables in period t. This cost is the sum of two components. One is $\beta \mathbb{E}_t \lambda_{t+1}$, which indicates the decline in utility caused by the reduction in tradable consumption in period $t+1$ necessary to repay the extra debt assumed in period t. The second component of the marginal cost is μ_t, which measures the shadow cost of tightening the borrowing limit. This second component is nil in periods in which $d_{t+1} < \bar{d}$, that is, in periods in which the borrowing limit does not bind.

2.2 Firms

The nontraded good is produced using labor as the sole factor input by means of an increasing and concave production function, $F(h_t)$. The firm operates in competitive product and labor markets. Profits, ϕ_t, are given by

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

The firm chooses h_t to maximize profits taking the relative price, p_t, and the real wage rate, w_t, as given. The optimality condition associated with this problem is

$$p_t F'(h_t) = w_t. \tag{10}$$

This first-order condition implicitly defines the firm's demand for labor. It states that firms are always on their labor demand curve. Put differently, in this model firms never display unfilled vacancies nor are forced to employ more workers than desired. As we will see shortly, this will not be the case for workers, who will in general be off their labor supply schedule and will experience involuntary unemployment.

2.3 Unemployment and Wages

Let W_t denote the nominal wage rate and E_t the nominal exchange rate, defined as the domestic-currency price of one unit of foreign currency. Assume that the law-of-one-price holds for traded goods and that the foreign-currency price of traded goods is constant and normalized to unity. Then, the real wage in terms of tradables is given by

$$w_t \equiv \frac{W_t}{E_t}.$$

An assumption that distinguishes the present setup from the existing related literature is that nominal wages are assumed to be downwardly rigid. Specifically, in any given period nominal wages can fall by at most the factor $\gamma \in [0, 1]$. Formally, we impose that

$$W_t \geq \gamma W_{t-1}.$$

This setup nests the cases of absolute downward rigidity, when $\gamma \geq 1$, and full wage flexibility, when $\gamma = 0$. The presence of nominal wage rigidity implies the following restriction on the dynamics of real wages:

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

where

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

denotes the gross nominal depreciation rate of the domestic currency.

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

$$h_t \leq \bar{h} \tag{12}$$

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

$$(\bar{h} - h_t)\left(w_t - \gamma \frac{w_{t-1}}{\epsilon_t}\right) = 0. \tag{13}$$

2.4 General Disequilibrium

Market clearing in the nontraded sector requires that

$$c_t^N = F(h_t). \tag{14}$$

Combining this market clearing condition, the definition of firm profits, and the household's sequential budget constraint, equation (3), yields

$$c_t^T + d_t = y_t^T + \frac{d_{t+1}}{1 + r_t}. \tag{15}$$

We can then define the general disequilibrium of the economy as follows:

Definition 1 (General Disequilibrium Dynamics) *The general disequilibrium dynamics are given by stochastic processes c_t, c_t^T, c_t^N, h_t, p_t, w_t, d_{t+1}, λ_t, and μ_t satisfying (2) and (4)-(15) given the exogenous stochastic processes y_t^T and r_t, an exchange rate policy ϵ_t and initial conditions w_{-1} and d_0.*

We consider two polar cases for the yet unspecified exchange rate policy: the optimal exchange-rate policy and a currency peg.

3 Optimal Exchange-Rate Policy

Consider an exchange-rate arrangement 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 monetary arrangement as the full-employment exchange-rate policy. This policy amounts to setting the devaluation rate to ensure that the real wage equals the flexible-wage real wage rate at all times. Formally, the optimal policy ensures that

$$w_t = \omega(c_t^T),$$

where $\omega(c_t^T)$ denotes the flexible-wage real wage rate and is given by

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

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

$$\omega'(c_t^T) > 0.$$

The optimal exchange-rate policy stipulates that should the nominal value of the flexible-wage 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 $\omega(c_t^T)E_t = \gamma W_{t-1}$. That is, the devaluation rate makes the nominal wage, W_t, equal to its lower bound, γW_{t-1}, and at the same time guarantees that the real wage, w_t, equal the flexible-wage real wage $\omega(c_t^T)$. If, in this case, the central bank chose not to devalue, the economy would experience unemployment, because downward wage rigidities would prevent the real wage from falling to the flexible-wage level $\omega(c_t^T)$.

On the other hand, if the nominal value of the flexible-wage real wage evaluated at the nominal exchange rate of the previous period, $\omega(c_t^T)E_{t-1}$, exceeds the lower bound γW_{t-1}, then the monetary authority keeps the nominal exchange rate constant, that is, it sets $E_t = E_{t-1}$ or equivalently, $\epsilon_t = 1$. There is no need for a devaluation in this case, because the nominal wage rate will adjust upward on its own accord (recall that nominal wages are assumed to be fully flexible upwardly). Alternatively, one could assume that in this case the central bank revalues the currency to avoid an increase in the nominal wage rate. Under both nominal exchange rate responses, the real allocation would be the same. In our view the case of no revaluation is the one of greatest empirical interest. For central banks in emerging countries are typically reluctant to revalue their currency.

It follows that under the full-employment exchange-rate policy, the gross devaluation rate is given by

$$\epsilon_t = \max\left\{1, \gamma \frac{w_{t-1}}{\omega(c_t^T)}\right\}. \tag{16}$$

The complete set of equilibrium conditions under the optimal exchange rate regime are then given by Definition 1 and the exchange rate policy given in equation (16).

Because under the optimal exchange-rate policy the real wage rate is always equal to the flexible-wage real wage, equation (16) implies that for all $t > 0$ the devaluation rate is given by

$$\epsilon_t = \max\left\{1, \gamma\frac{\omega(c^T_{t-1})}{\omega(c^T_t)}\right\}; \quad t > 0. \tag{17}$$

Recalling that $\omega(.)$ is a strictly increasing function of tradable absorption, this expression states that the central bank will devalue the domestic currency only when tradable expenditure falls. We note that in light of this result, non-microfounded statistical analysis would conclude that devaluations are contractionary. However, the role of devaluations under the optimal exchange-rate policy is precisely the opposite, namely, to prevent the contraction in the tradable sector to spill over into the nontraded sector. It follows that under the optimal exchange-rate policy, devaluations are indeed expansionary in the sense that should they not take place, aggregate contractions would be even larger. Thus, under the optimal exchange-rate regime, our model with downward nominal-wage rigidities turns the view that 'devaluations are contractionary' on its head and instead predicts that 'contractions are *devaluatory*.'

Note that under the optimal exchange-rate policy and under our maintained assumption of no revaluations, the average devaluation rate is positive ($\mathbb{E}\epsilon_t > 1$). This result follows directly from the fact that, by equation (16), the equilibrium gross devaluation rate is time varying and bounded below by unity. The inflation rate in the nontraded sector is also positive on average. To see this, notice that the relative price of nontradables, p_t, is given by the ratio of the nominal price of nontradables and the nominal exchange rate. Because in our model the relative price of nontradables is a stationary variable and the nominal exchange rate grows on average at a positive rate, it follows that the nominal price of nontradables must also grow on average at a positive rate, which means that the inflation rate in the nontraded sector must be positive on average. The aggregate rate of inflation is then also positive on average, because it is a weighted average of the inflation rates of the traded and nontraded sectors. Therefore, in the case in which the central bank conducts optimal exchange rate policy but fears revaluations, our model formalizes Olivera's (1960, 1964) structural or nonmonetary theory of the optimality of positive inflation.[1] The reason for this Olivera-style result is that in this case not only the nominal wage rate but also the nominal exchange are downwardly rigid, so any reaccommodation of relative prices must be brought about through inflation. If the central bank did not fear revaluations, then the Olivera-style structural inflation bias need not obtain. For appropriate revaluations in periods in which the real exchange rate appreciates would guarantee long run price stability.

The full-employment exchange-rate policy completely eliminates all real effects stemming from nominal wage rigidities. Indeed, it is straightforward to show that the equilibrium

[1]See also Tobin (1972).

under the optimal exchange-rate policy is identical to the competitive equilibrium of an economy with full wage flexibility. Since wage rigidity is the only source of distortion in the present model, it follows that the equilibrium under the full-employment exchange-rate policy is Pareto optimal. The equilibrium dynamics under the optimal exchange-rate policy can therefore be characterized as the solution to the following value function problem:

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

subject to (4) and (15), where the function $v^O(y_t^T, r_t, d_t)$ represents the welfare level of the representative agent under the full-employment exchange-rate policy in state (y_t^T, r_t, d_t). The equilibrium processes of all other endogenous variables of the model can be readily obtained from (16) and the conditions listed in Definition 1. The fact that the aggregate dynamics under optimal exchange rate policy can be described as the solution to a Bellman equation greatly facilitates the quantitative characterization of the model's predictions. We turn to this task next.

4 Crisis Dynamics Under the Optimal Exchange-Rate Policy

We numerically approximate the equilibrium dynamics under optimal exchange rate policy by applying the method of value function iteration over a discretized state space. To this end we begin by adopting explicit functional forms for preferences and technology. We assume a CRRA form for the period utility function, a CES form for the aggregator function and an isoelastic form for the production function of nontradables:

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

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

and

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

We calibrate the model at a quarterly frequency using data from Argentina as shown in table 1. Reinhart and Végh (1995) estimate the intertemporal elasticity of substitution to be 0.21 using Argentine quarterly data. We therefore set σ equal to 5. We normalize the steady-state levels of output of tradables and hours at unity. Then, if the steady-state

Table 1: Calibration

Parameter	Value	Description
σ	5	Inverse of intertemporal elasticity of consumption
y^T	1	Steady-state tradable output
$\bar{h}$	1	Labor endowment
a	0.26	Share of tradables
ξ	0.44	Elasticity of substitution between tradables and nontradables
α	0.75	Labor share in nontraded sector
γ	0.99,0.98	Degree of downward nominal wage rigidity
β	0.9375	Quarterly subjective discount factor

trade-balance-to-output ratio is small, the parameter a is approximately equal to the share of traded output in total output. We set this parameter at 0.26, which is the share of traded output (to be defined below) observed in Argentine data over the period 1980:Q1-2010:Q1. We set the elasticity of substitution between traded and nontraded consumption, ξ, to 0.44 following González Rozada et al. (2004). These authors estimate ξ using time series data for Argentina for the period 1993Q1-2001Q3. A value of 0.44 is also 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.

The law of motion of tradable output and the country-specific interest rate is given by the following autoregressive process:

$$\begin{bmatrix} \ln y_t^T \\ \ln \frac{1+r_t}{1+r} \end{bmatrix} = A \begin{bmatrix} \ln y_{t-1}^T \\ \ln \frac{1+r_{t-1}}{1+r} \end{bmatrix} + \epsilon_t, \tag{18}$$

where ϵ_t is a white noise of order 2 by 1 distributed $N(\emptyset, \Sigma_\epsilon)$. The parameter r denotes the deterministic steady-state value of r_t. We estimate this system using Argentine data over the period 1983:Q1 to 2001:Q4. We exclude the period post 2001 because Argentina was in default between 2002 and 2005 and excluded from international capital markets. The default was reflected in excessively high country premia. Excluding this period is in order because interest rates were not allocative, which is at odds with our maintained assumption that the government never loses access to international financial markets. This is a conservative choice, for inclusion of the default period would imply a more volatile driving force accentuating the real effects of currency pegs on unemployment. Our empirical measure of y_t^T is the cyclical component of Argentine GDP in agriculture, forestry, fishing, mining, and manufacturing. We obtain the cyclical component by removing a log-quadratic time trend. We measure the country-specific real interest rate as the sum of the EMBI+ spread for Argentina and the 90-day Treasury-Bill rate, deflated using a measure of expected dollar inflation.[2] Our OLS estimates of the matrices A and Σ_ϵ and of the scalar r are

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

According to our 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 (6.8 percent per year), respectively. Also, the unconditional contemporaneous correlation between $\ln y_t^T$ and r_t is high and negative at -0.86. This means that periods of relatively high traded output are associated with low interest rates and vice versa. The estimated joint autoregressive process implies that both traded output and the real interest rate are highly persistent, with first-order autocorrelations of 0.95 and 0.93, respectively. Finally, we estimate a steady-state real interest rate of 3.16 percent per quarter, or 12.6 percent per year. This high average level of interest reflects the fact that our sample covers a period in which Argentina underwent a great deal of economic turbulence.

We discretize the AR(1) process given in equation (18) using 21 equally spaced points for $\ln y_t^T$ and 11 equally spaced points for $\ln(1 + r_t)/(1 + r)$.[3] We use 1001 equally spaced points in the discretization of external debt d_t.

A novel parameter in our model is γ, which measures the ability of firms to cut nominal wages without facing worker resistance. To our knowledge, no econometric estimate of this parameter exists for emerging countries. One difficulty in estimating γ, which applies to both emerging and developed country studies, is that it belongs to an occasionally binding constraint. Therefore, the econometrician cannot rely on an equation that holds in every period and features γ among its parameters. Also, empirical evidence on the observed

[2]Specifically, we construct the time series for the quarterly real Argentine interest rate, r_t, as $1+r_t = (1+i_t)E_t\frac{1}{1+\pi_{t+1}}$, where i_t denotes the dollar interest rate charged to Argentina in international financial markets and π_t is U.S. CPI inflation. For the period 1983:Q1 to 1997:Q4, we take i_t to be the Argentine interest rate series constructed by Neumeyer and Perri (2005) and posted at www.fperri.net/data/neuperri.xls. For the period 1998:Q1 to 2001:Q4, we measure i_t as the sum of the EMBI+ spread and the 90-day Treasury bill rate, which is in line with the definition used in Neumeyer and Perri. We measure $E_t\frac{1}{1+\pi_{t+1}}$ by the fitted component of a regression of $\frac{1}{1+\pi_{t+1}}$ onto a constant and two lags. This regression uses quarterly data on the growth rate of the U.S. CPI index from 1947:Q1 to 2010:Q2.

[3]We construct the transition probability matrix of the state $(\ln y_t^T, \ln((1 + r_t)/(1 + r)))$ by simulating a time series of length 1,000,000 drawn from the system (18). We associate each observation in the time series with one of the 231 possible discrete states by distance minimization. The resulting discrete-valued time series is used to compute the probability of transitioning from a particular discrete state in one period to a particular discrete state in the next period. The resulting transition probability matrix captures well the covariance matrices of order 0 and 1 of the two variables included in the system.

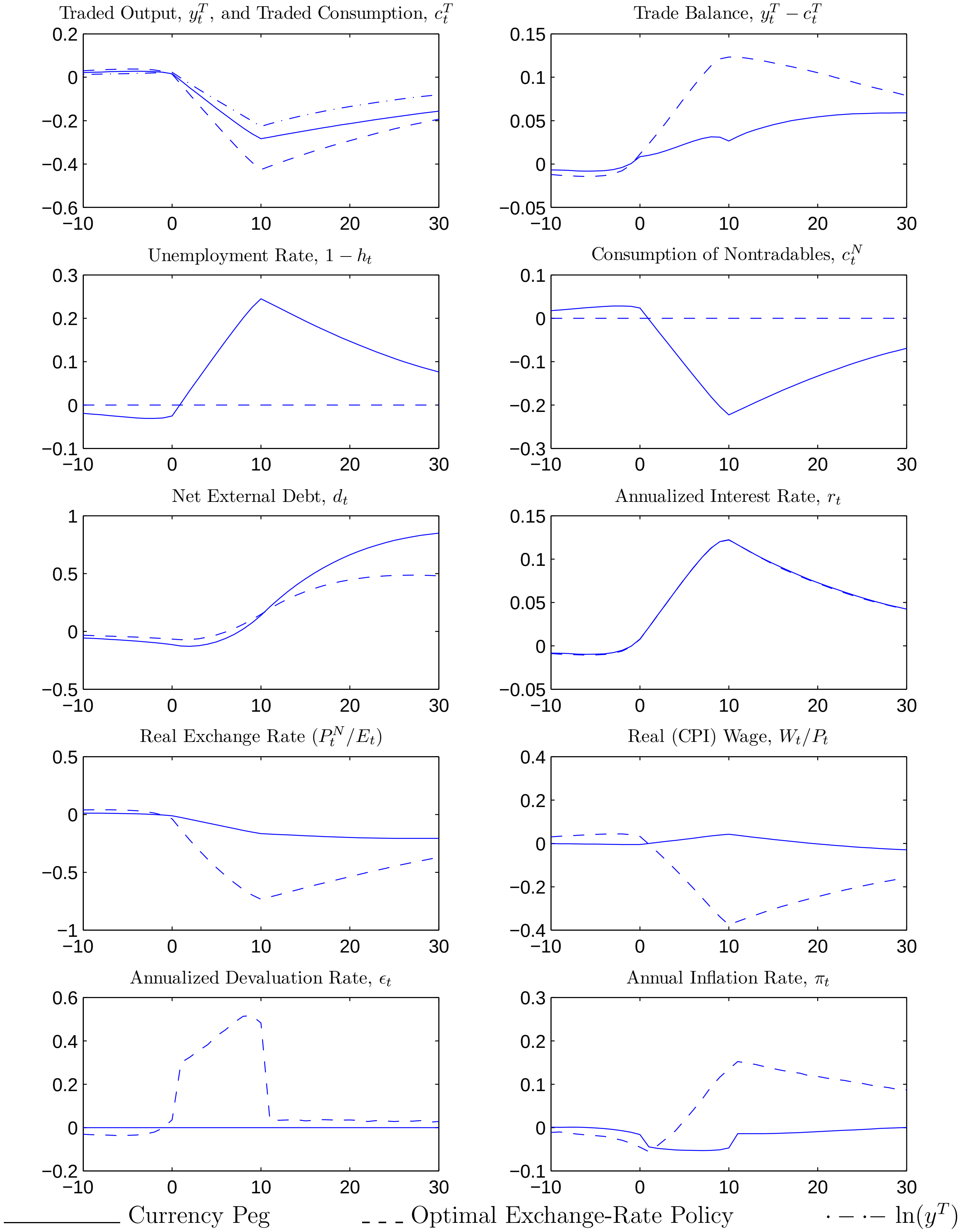
frequency of nominal wage cuts, taken in isolation, is in general not informative about the size of γ. The reason is that the frequency of observed wage cuts in general depends on the underlying monetary regime and in particular on the average level of inflation. For example, in the calibrated economy studied here, when γ equals 0.99, nominal-wage cuts occur 89 percent of the time under an exchange-rate peg (to be studied in detail in the next section) but only 50 percent of the time under the optimal policy. These figures could erroneously be interpreted as meaning that in the currency-peg economy nominal wages are less rigid than in the optimal-monetary-policy economy. In our benchmark calibration, we set γ equal to 0.99. This value implies that firms can cut nominal wages by 4 percent per year without encountering resistance on the part of workers. In the context of a currency peg, which induces an average inflation rate of zero, the benchmark value of γ implies that the real wage can fall frictionlessly by 4 percent per year.

The final parameter we calibrate is the subjective discount factor β. In the context of the current model, calibrating β is not an easy task. The reason is that given the value of β, the average level of the trade-balance-to-output-ratio and the debt-to-output ratio, which are typically used to calibrate β, depend on both the degree of wage stickiness and the assumed monetary regime. The latter factor is the most problematic because in emerging countries, monetary regimes tend to change frequently and widely. A compromise is therefore in order. We set β to 0.9375. This value implies an average net foreign debt to output ratio of 26 percent per year in the stochastic steady state when wages are allowed to fall frictionlessly by up to 4 percent per year ($\gamma = 0.99$), and monetary policy is characterized by a currency peg. A debt to output ratio of 26 percent is in line with the updated and extended version of the dataset constructed by Lane and Milesi-Ferretti (2007) for Argentina over our calibration period.

Figure 1 displays with broken lines the average response of the economy under the optimal exchange-rate policy to a crisis caused by a large negative endowment shock in the traded sector. The crisis depicted in the figure can be interpreted as caused by a large deterioration in the country's terms of trade. These responses are constructed as follows. We simulate the economy for 20 million quarters. We then identify all quarters t in which tradable output is at or above trend in period t and at least two standard deviations below trend in period $t+10$. We refer to t as the beginning of the crisis and to $t+10$ as the trough of the crisis. We find about 76,000 crisis episodes. This means that the crises we identify occur approximately once every 66 years. We then average the responses of all variables of interest across the 76,000 episodes within the window t-10 to t+30. In figure 1, the starting point of the crisis is normalized at 0.

At the trough of the crisis (period 10), tradable output is 23 percent below trend. The

Figure 1: The Dynamics of a Crisis: Response to a Two-Standard-Deviation Fall in y_t^T



contraction in tradable output is accompanied by a sharp increase in the interest rate that international financial markets charge to the emerging economy. The country interest rate peaks in quarter 10 at about 12 percentage points per annum above its average value. This behavior of the interest rate is exclusively dictated by the estimated negative correlation between tradable output and country interest rates. The collapse in tradable output and the interest-rate hike both exert substantial downward pressure on domestic absorption of tradables as well as nontradable goods. To maintain full employment in the nontraded sector, the government engineers a significant expenditure switch away from tradables and toward nontradables. The instrument the government uses to accomplish this expenditure switch is a series of large devaluations of the domestic currency of about 40 percent per year during the contractionary phase of the crisis. The main purpose of these devaluations is to lower labor costs in the nontraded sector thereby depreciating the real exchange rate, i.e., lowering the relative price of nontradable goods in terms of tradable goods. The purchasing power of wages in terms of the composite consumption good, W_t/P_t, falls by about 40 percent and the real exchange rate, $p_t \equiv P_t^N/E_t$, depreciates by about 70 percent, where $P_t \equiv \left[a^{\xi} E_t^{1-\xi} + (1-a)^{\xi} {P_t^N}^{1-\xi}\right]^{\frac{1}{1-\xi}}$, denotes the nominal price of one unit of the composite consumption good in period t, and P_t^N denotes the nominal price of one unit of nontradable consumption in period t. It follows that the nominal price of nontradables remains relatively flat as the large nominal devaluations occur. This prediction of our model is remarkable because nominal prices of nontradables are assumed to be fully flexible. The predicted sluggish adjustment of the nominal price of nontradables is in line with the empirical findings of Burstein, Eichenbaum, and Rebelo (2005) who report that the primary force behind the observed large drop in the real exchange rate that occured after the large devaluations in Argentina (2002), Brazil (1999), Korea (1997), Mexico (1994), and Thailand (1997) was the slow adjustment in the nominal prices of nontradable goods.

In the tradable sector, the expenditure switch is reflected in a drastic fall in tradable consumption of about 40 percent. In fact the fall in the domestic absorption of tradable goods is larger than the contraction in the supply of tradables. This results in a significant reversal in the trade balance, which improves from slightly below trend to about 10 percent of tradable GDP above trend. However, because of the elevated debt-service cost stemming from the interest-rate hike, the large improvement in the trade balance is not sufficient to prevent external debt from growing during the crisis.

The large optimal devaluations that take place during the crises are prima facie an indication that rigidly adhering to a currency peg during times of duress might carry nontrivial real effects in terms of unemployment, output, and welfare. We turn to this issue next.

5 Crisis Dynamics Under A Currency Peg

At center stage in our analysis is the characterization of the costs of maintaining a currency peg. A currency peg is meant to capture, for example, the monetary policy in place in Argentina between April 1991 and December 2001 or the monetary restrictions faced by the small emerging economies that are members of the Eurozone, such as Greece, Portugal, and Ireland. Under a currency peg the government commits to keeping the nominal exchange rate constant over time, $E_t = E_{t-1}$ for $t \geq 0$. As a result, the gross rate of devaluation equals unity at all times:

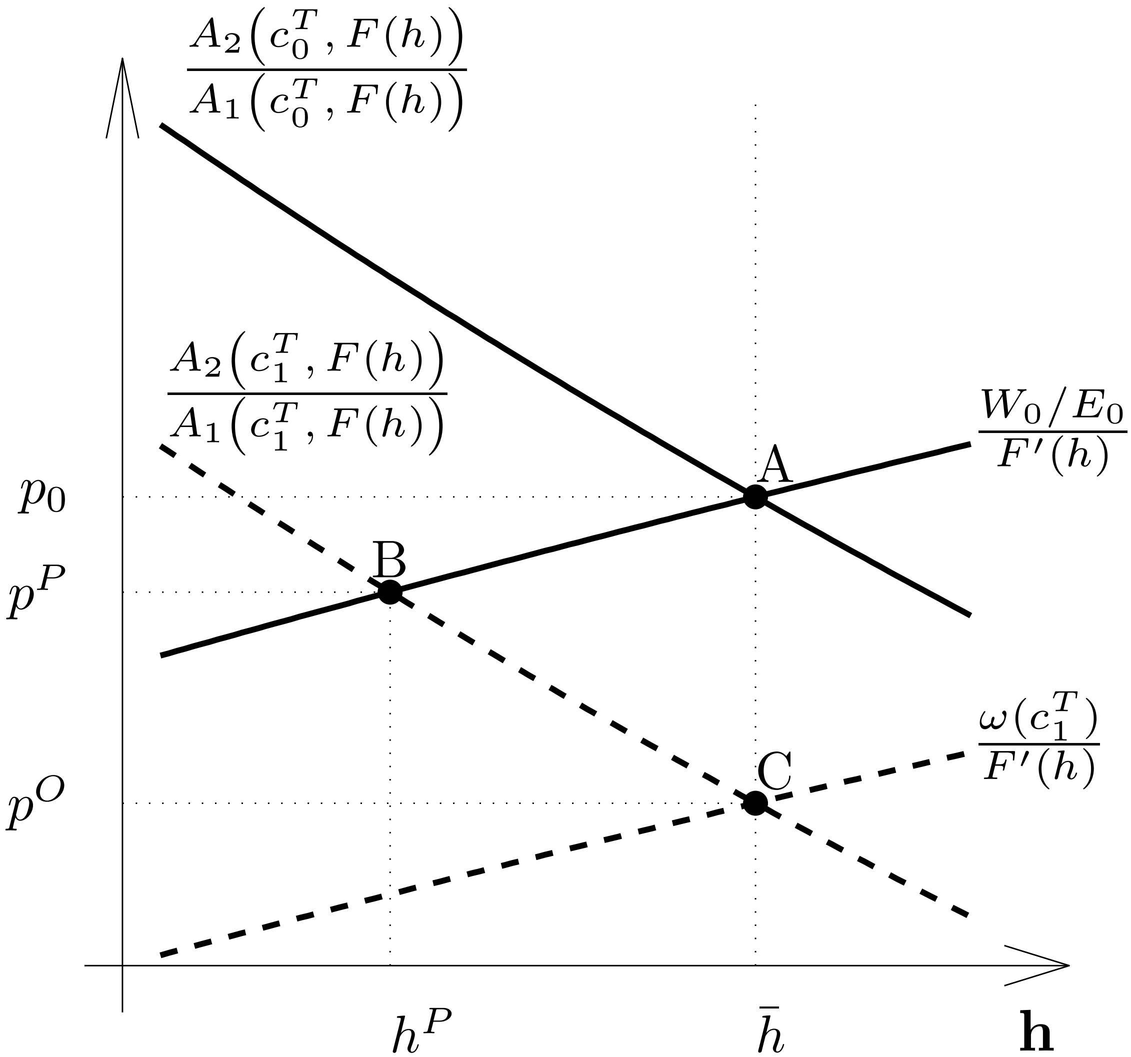
$$\epsilon_t = 1, \tag{19}$$

for $t \geq 0$. Aggregate disequilibrium dynamics under a currency peg are then given by the exchange-rate policy (19) and the conditions listed in Definition 1.

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, under a currency peg, the real wage expressed in terms of tradables, w_t, is downwardly rigid, and adjusts only sluggishly, at the rate $(1-\gamma)$, to negative demand shocks. The labor market is, therefore, in general, in disequilibrium and features involuntary unemployment. The magnitude of the labor market disequilibrium 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.

Figure 2 depicts qualitatively the general disequilibrium for a given value of the aggregate domestic absorption of tradable goods, c^T. The initial desired level of tradable absorption is c_0^T. The function $A_2(c_0^T, F(h))/A_1(c_0^T, F(h))$ represents the price households are willing to pay for a unit of nontradable goods as a function of employment in the nontraded sector, h. Given c_0^T, this schedule is downward sloping because an increase in employment raises the supply of nontradables lowering the price at which households are willing to purchase the increased quantity. We refer to this schedule as the price function. The locus $(W_0/E_0)/F'(h)$ represents the marginal cost of producing nontradables as a function of h, given the real wage rate W_0/E_0, where W_0 denotes the initial nominal wage rate and E_0 denotes the initial nominal exchange rate. This schedule is increasing in h because of the assumed diminishing marginal product of labor in the nontraded sector. Market clearing in the nontraded sector occurs at a level of employment at which the price function intersects the marginal cost function, point A in the figure. By construction, at point A the economy enjoys full employment ($h = \bar{h}$) and the relative price of nontradables is equal to p_0.

Figure 2: General Disequilibrium



Suppose now that a negative demand shock, such as a deterioration in the terms of trade or a rise in the country premium, causes a decline in the desired aggregate absorption of tradables from c_0^T to $c_1^T < c_0^T$. This adverse shock causes the price function to shift down and to the left. At the same time the marginal cost schedule does not shift. This is because the combination of a currency peg and nominal downward rigidity of wages prevents the real wage from adjusting downward. The new intersection of the price and marginal cost schedules occurs at point B. At this point, employment is equal to $h^p < \bar{h}$ and the economy suffers from unemployment at the rate $\bar{h} - h^P$, where h^P denotes the level of employment that obtain under the currency peg. Alternatively, suppose that in response to the negative external shock, 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 optimal level $E^O > E_0$ satisfying $W_0/E^O = \omega(c_1^T)$, where $\omega(c_1^T)$ denotes the flexible-wage real wage rate. In this case the marginal cost schedule would shift down and to the right intersecting the new price schedule at point C, where unemployment is nil ($h = \bar{h}$). A further difference in the macroeconomic adjustment under a currency peg and the optimal exchange rate policy is that under a currency peg the relative price of non-tradables falls by less than under the optimal exchange rate policy. Specifically, in the figure the relative price of nontradables falls to p^P, whereas under the optimal policy, the relative price falls to $p^O < p^P$. This insufficient decline in the relative price of nontradables stands in the way of households switching expenditures away from tradables and toward nontradables, which is the root of the unemployment and excessive-debt-volatility problems associated with currency pegs.

Approximating the dynamics of the model under a currency peg is computationally more demanding than doing so under optimal exchange-rate policy due to the emergence of a fourth state variable, w_{t-1}. In addition, the disequilibrium dynamics cannot be cast in terms of a Bellman equation because of the distortions introduced by nominal rigidities. We therefore approximate the solution by Euler equation iteration over a discretized version of the state space $(y_t^T, r_t, d_t, w_{t-1})$. The discretization of the exogenous states y_t^T and r_t is as described in section 4. For the discretization of the endogenous states, we use 501 equally spaced points for external debt, d_t, and 500 equally spaced points for the logarithm of w_{t-1}. The calibration of the model is the same as the one discussed in section 4.

Figure 1 depicts with solid lines the dynamics induced by a large crisis when the monetary policy takes the form of an exchange-rate peg. As in section 4, a crisis is defined as the average response of the economy to a situation in which in period 0 tradable output is at or above trend and in period 10 it is at least two standard deviations below trend. By construction, the behavior of the exogenous variables, traded output and the country interest rate, are identical to that shown for the case of optimal exchange-rate policy.

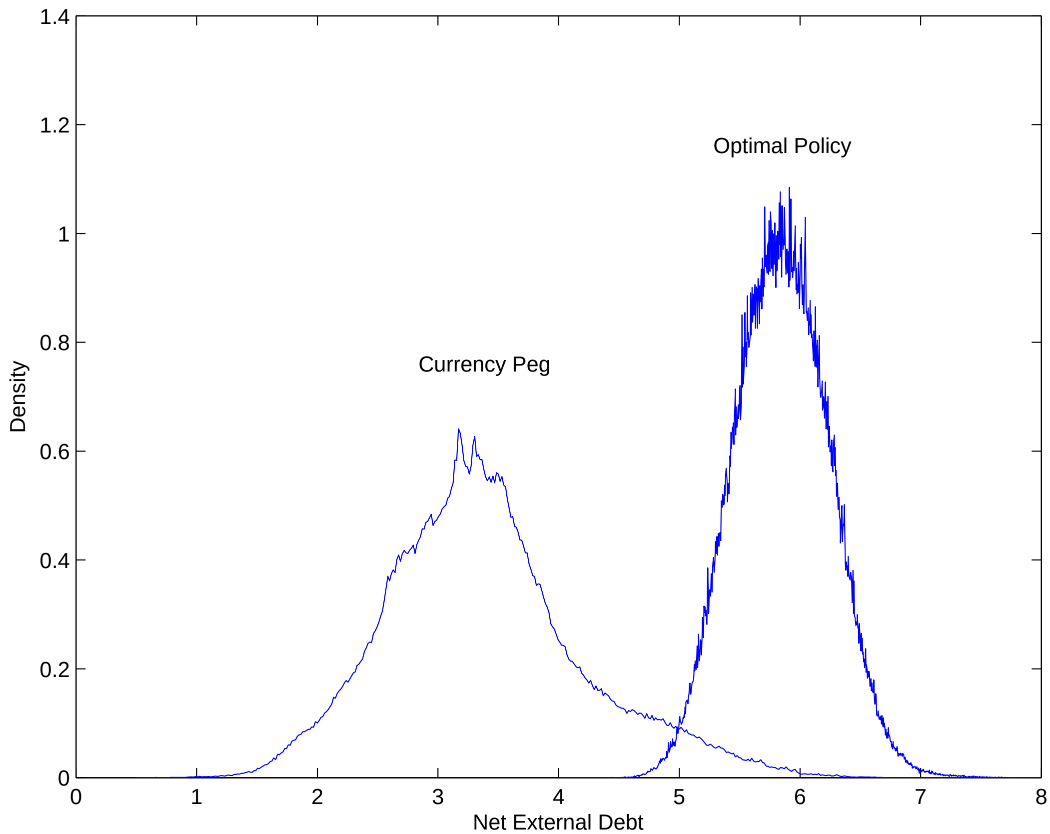
The central difference in the response to an external crisis between the currency-peg economy and the optimal-exchange-rate economy is that under a currency peg the contraction in the traded sector spills over to the nontraded sector. This is because the monetary authority fails to devalue the domestic currency preventing real wages and thus also marginal costs in the nontraded sector from adjusting downward (see row 4, column 2 of figure 1). With real wages too high, the labor market is in disequilibrium and unemployment emerges (see row 2, column 1). At the same time, because marginal costs are high, firms are unwilling to cut the relative price of nontradables (see row 4, column 1 of figure 1). Consequently, there is no expenditure switching away from tradables toward nontradables. Put differently, the combination of downward nominal wage rigidity and a currency peg hinders the ability of the price system to signal to firms and consumers the relative aggregate scarcity of tradable goods and the relative aggregate abundance of nontradable goods.

The collapse in the demand for nontradables pushes the unemployment rate up by more than 20 percentage points. Importantly, unemployment is highly persistent. Even five years after the trough of the crisis, the unemployment rate remains more than 7 percentage points above average. This sluggishness in unemployment is due to the fact that real wages adjust slowly downward at the rate γ. The predicted unemployment is involuntary, in the sense that every unemployed individual would be willing to work at the going wage rate.

The predictions of our disequilibrium model suggest that a hands-off policy approach whereby the necessary real depreciation is let to occur via deflation, while maintaining a currency peg, is highly costly in terms of unemployment and forgone consumption. Although the currency-peg economy displays a mild deflation during the crisis (see row 5, column 2 of figure 1), the fall in nominal product prices is too small and too slow to bring about the efficient real depreciation required to avoid unemployment. It is interesting to point out that nominal product prices fail to decline to the level consistent with full employment in spite of the fact that they are fully flexible. The reason for the seemingly sticky behavior of product price inflation is that, because nominal wages are downwardly rigid, marginal costs remain high and therefore firms are unable to cut prices without making losses.

A further distortion introduced by the combination of downward wage rigidity and a currency peg is an excessive absorption of tradable goods during the crisis (see row 1, column 1 of figure 1). The excess consumption of tradables (relative to what is optimal) is driven by the fact that the exchange rate does not depreciate sufficiently in real terms. Under a currency peg the improvement in the trade balance during the crisis is more modest than under the optimal exchange rate policy, spurring a more rapid rise in external debt driven by the higher interest rates (see row 1, column 2 and row 3, column 1 of figure 1).

Figure 3: The Distribution of External Debt



Indeed, the suboptimal behavior of the external debt affects the country's long-run ability to accumulate external financial obligations. Figure 3 displays the unconditional distribution of the external debt in the stochastic steady state of the currency-peg and optimal-exchange-rate economies. The debt distribution associated with the optimal-exchange-rate economy features a higher mean and is more concentrated about the mean than the debt distribution associated with the currency-peg economy. Specifically, the mean debt under the optimal exchange-rate policy is 5.8 (or 146 percent of the annual steady-state endowment of traded goods) and the standard deviation is 0.4 (or 10 percent of the traded endowment). By contrast, in the currency-peg economy the mean external debt is 3.4 (or 84 percent of annual tradable output) with a standard deviation of 0.8 (or 20 percent of annual tradable output).

These differences in the distribution of the level of external debt are due to the fact that in the currency-peg economy the price mechanism that induces households to drastically cut their absorption of tradable goods during periods in which the traded endowment is low and the interest rate is high malfunctions due to the real rigidity imposed by the combination of downward nominal wage rigidity and a currency peg. During crises, the currency-peg economy takes on too much external debt. The resulting path of debt is excessively volatile. The only way such debt dynamics can be supported in the long-run is by lowering the average level of external debt. In summary, inefficient short-run volatility acts as a borrowing constraint and has long-run effects on the debt distribution. The prediction that the average level of external debt is higher under the optimal exchange-rate policy than under a currency peg depends on the relative magnitudes of the intra- and intertemporal elasticities of substitution, ξ and $1/\sigma$, respectively. Our baseline calibration assumes that the intratemporal elasticity exceeds the intertemporal elasticity, 0.44 versus 0.2. However, if the intertemporal elasticity of substitution is set at a higher value than the intratemporal elasticity, it becomes possible that the average level of external debt is higher in the currency peg economy than in the optimal exchange-rate economy.

6 The Welfare Costs of Currency Pegs

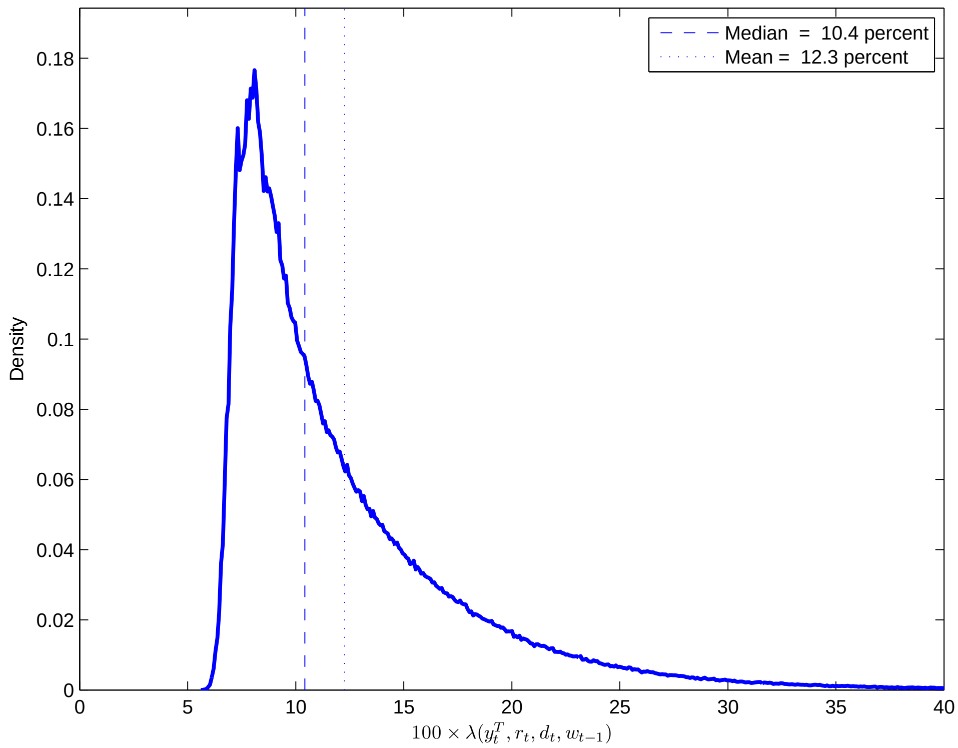
In our model, there are two sources of welfare loss associated with a currency peg. One is that a currency-peg economy is prone to persistent unemployment spells (see figure 1). Under our calibration the average unemployment rate under a currency peg is 14 percent. As a consequence the average supply of nontraded goods is lower than in the optimal exchange rate economy, in which unemployment is zero at all times. The second source of welfare loss is that the currency-peg economy experiences large swings in net foreign asset holdings, and, as a consequence, must overaccumulate external assets to maintain solvency (see figure 3). We quantify the welfare cost of living in an economy in which the central bank pegs the currency by computing the percent increase in the consumption stream of the representative household living in the currency-peg economy that would make him as happy as living in the optimal-exchange-rate economy. This computation must take explicitly into account the transitional dynamics induced by the switch from a peg to the optimal policy. Specifically, one can express the value function associated with the currency-peg economy as

$$v^P(y_t^T, r_t, d_t, w_{t-1}) = E_t \sum_{s=0}^{\infty} \beta^s \frac{\left(c_{t+s}^P\right)^{1-\sigma} - 1}{1-\sigma},$$

where c_t^P denotes the stochastic process of consumption of the composite good in the currency-peg economy. Then, define the proportional compensation rate $\lambda(y_t^T, r_t, d_t, w_{t-1})$ implicitly as

$$E_t \sum_{s=0}^{\infty} \beta^s \frac{\left[c_{t+s}^P(1+\lambda(y_t^T, r_t, d_t, w_{t-1}))\right]^{1-\sigma} - 1}{1-\sigma} = v^O(y_t^T, r_t, d_t).$$

Figure 4: Probability Density Function of the Welfare Cost of Currency Pegs



Solving for $\lambda(y_t^T, r_t, d_t, w_{t-1})$, we obtain

$$\lambda(y_t^T, r_t, d_t, w_{t-1}) = \left[\frac{v^O(y_t^T, r_t, d_t)(1-\sigma) + (1-\beta)^{-1}}{v^P(y_t^T, r_t, d_t, w_{t-1})(1-\sigma) + (1-\beta)^{-1}}\right]^{1/(1-\sigma)} - 1.$$

This expression makes it clear that the compensation $\lambda(y_t^T, r_t, d_t, w_{t-1})$ is state dependent. Specifically, the distribution of $\lambda(y_t^T, r_t, d_t, w_{t-1})$ depends upon the distribution of the state $(y_t^T, r_t, d_t, w_{t-1})$. The ergodic distributions of debt under the currency peg and under the optimal policy do not have the same support. Therefore, in order to compute $\lambda(y_t^T, r_t, d_t, w_{t-1})$ one must evaluate the welfare function $v^O(y_t^T, r_t, d_t)$ at levels of debt outside of the support of its ergodic distribution under the optimal policy. Having computed $\lambda(y_t^T, r_t, d_t, w_{t-1})$ for all values of the state in its ergodic distribution under the currency peg, we proceed to compute the probability density function of $\lambda(y_t^T, r_t, d_t, w_{t-1})$ by sampling from the ergodic distribution of the state under the currency peg.

Figure 4 displays with a solid line the unconditional probability density function of $\lambda(y_t^T, r_t, d_t, w_{t-1})$ expressed in percentage points. The probability density is highly skewed to the right, making the median, shown with a dashed line, a more meaningful statistic than the mean, shown with a dotted line. The unconditional median of the welfare cost of a currency peg is 10.4 percent of the consumption stream. That is, households living in a currency peg economy require 10.4 percent more consumption in every date and state in order to be indifferent between staying in the currency-peg regime and switching to the optimal-exchange-rate regime. This is an enormous number as welfare costs go in monetary business-cycle theory. Even under the most favorable initial conditions, the welfare cost of a currency peg is large, 5.6 percent of consumption each period. (This figure corresponds to the lower bound of the support of the probability density of $\lambda(y_t^T, r_t, d_t, w_{t-1})$.)

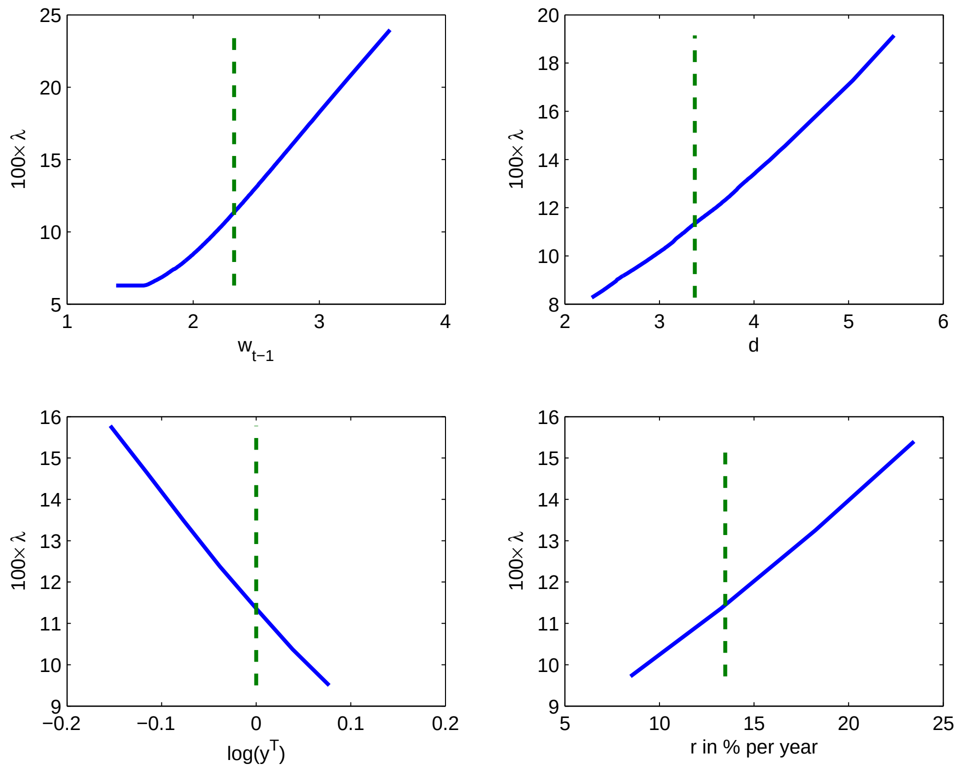
The long-run effects of the exchange-rate regime on asset accumulation play an important role in determining the cost of currency pegs. Under a peg, the inability of relative prices to correctly signal the relative scarcity of traded goods implies large swings in the country's external debt position (see figure 3). As a consequence of the high volatility in the net debt position, risk-averse agents overaccumulate foreign assets. This excessive asset accumulation is costly. A switch from a currency peg to the optimal exchange-rate regime allows agents to reduce their average asset holdings, which results in temporarily high levels of consumption of tradable goods.

The welfare consequences of unemployment under a currency peg are reflected in the implied average levels of consumption. Eventhough the currency-peg economy enjoys 8.5 percent higher average consumption of tradables (due to lower average debt holdings), aggregate consumption under the currency peg is 5 percent lower than under the optimal exchange rate policy. This is because due to unemployment in the nontraded sector, consumption of nontradables under the currency peg is on average 11 percent lower than under the optimal exchange rate regime.

Figure 5 displays the welfare cost of currency pegs as a function of the four state variables. In each panel only one state variable is allowed to vary (along the horizontal axis) and the remaining three state variables are fixed at their respective unconditional means (under a currency peg, in the case of endogenous states). The figure shows that countries have more incentives to abandon a peg when they are more indebted, when the tradable sector is undergoing a contraction (due, for example, to unfavorable terms of trade), when the country interest-rate premium is high, and when the country starts with high past real wages. Viewing the recent debt crisis among European-Union emerging countries through the lens of our model, it is not difficult to understand why doubts about the optimality of European monetary union are the strongest for member countries like Greece, Portugal, and Spain:[4] These are countries with highly inflexible labor markets, large levels of debt, high

[4]For instance, in his May 7th, 2010 OP-ED column in the New York Times entitled "A Money Too Far," Paul Krugman writes "The only thing that could seriously reduce Greek pain would be an economic recovery. [...] If Greece had its own currency, it could try to engineer such a recovery by devaluing that currency, increasing its export competitiveness. But Greece is on the Euro."

Figure 5: Welfare Cost of Currency Pegs as a Function of the State Variables



Note. In each plot, all states except the one shown on the horizontal axis are fixed at their unconditional mean values. The dashed vertical lines indicate the unconditional mean of the state displayed on the horizontal axis (under a currency peg if the state is endogenous).

Table 2: Sensitivity Analysis

Parameterization	Welfare Cost of Currency Peg	
	Median	Mean
Baseline	10.4	12.3
Higher patience ($\beta = 0.945$)	8.0	9.2
Higher elasticity of substitution ($\xi = 0.88$)	8.6	10.8
Higher intertemporal elast. of sub. ($\sigma = 2$)	9.9	10.8
Less downward rigidity ($\gamma = 0.98$)	6.7	8.1

country premia, and negative terms-of-trade shocks.

7 Sensitivity Analysis

In this section, we study how the welfare costs of currency pegs are affected by alternative parameterizations of the model. We begin by considering the case that households are more patient. The reason for considering this case is that in principle there exist two equivalent strategies to calibrate the subjective discount factor β. One strategy is to match the mean net external debt to output ratio. The other is to match the mean trade-balance-to-output ratio. When working with actual data, however, these two strategies are not equivalent because of the necessity to use finite samples and because of the presence of measurement error. In our baseline calibration we adopted the strategy of matching the average debt-to-output ratio in Argentina, which as mentioned earlier was 26 percent over the calibration period. This approach delivers a trade-balance-to-output ratio of 3.7 percent which is higher than the value of 2.2 percent observed over our calibration period. We now calibrate β so as to match this value of the trade-balance-to-output ratio. This requires raising β from its baseline value of 0.9375 to 0.945. The raising of the discount factor results in a decline in the average debt-to-output ratio in the currency peg economy from 26 to 15 percent of annual output. Table 2 shows that under this alternative calibration the welfare costs of a currency peg relative to the optimal exchange rate policy has a median of 8 percent and a mean of 9.2 percent of the consumption stream. These figures are smaller than those corresponding to the baseline calibration but still extremely large as costs of business cycles go. As discussed earlier, in our economy with downwardly rigid wages a currency peg acts like a borrowing constraint. This is because a currency peg induces a more dispersed debt distribution, which requires a lower mean debt (or higher precautionary savings) to ensure long-run solvency. More patient agents are in general less negatively affected by a given borrowing limit than are less patient agents. This explains why the welfare cost of a currency peg under the current calibration is smaller than under the baseline calibration.

An important parameter in our model is ξ measuring the intratemporal elasticity of substitution between traded and non-traded goods. The reason why this parameter is important in our model is that the higher is the elasticity of substitution between tradables and nontradables, the smaller is the real depreciation required to bring about the necessary expenditure switch away from tradables and towards nontradables in response to negative aggregate demand shocks. It follows that the higher is ξ the less disruptive is the presence of nominal downward rigidities in wages for macroeconomic adjustment. We therefore consider a value of ξ that is twice as large as our baseline value. This value is in line with the one obtained by restricting the cross-country sample of Stockman and Tesar (1995) to include only developed countries, (see Akinci 2011). This higher value of ξ is also consistent with the estimates reported in Ostry and Reinhart (1992) for a panel of Latin American countries. Consistent with our intuition, we find that the average unemployment rate falls from 15 to 11 percent as ξ increases from its baseline value of 0.44 to 0.88. And the median welfare cost of a currency peg relative to the optimal exchange-rate policy falls from 10.4 to 8.6 percent of the consumption stream. These figures show that even in an environment in which consumers can substantially more easily substitute tradables for nontradables, currency pegs continue to be extremely painful.

We also investigate the sensitivity of our findings to increasing the intertemporal elasticity of substitution, $1/\sigma$. Specifically, we lower σ from its baseline value of 5 to a value of 2. This latter value is widely used in emerging-country business-cycle analysis, see Uribe (2011) and the references cited therein. Raising the intertemporal elasticity of substitution makes households less risk averse and as a result more willing to assume external debt. Holding all parameters other than σ constant at their baseline values, the lowering of σ results in debt distribtutions (under both the currency peg regime and the optimal exchange-rate regime) that pile up to the left of the natural debt limit. The implied debt-to-output ratios are many times larger than those observed over our calibration period. For this reason, we adjust the value of β from its baseline value of 0.9375 to 0.964 to ensure that together with a value of $\sigma = 2$, the currency-peg economy delivers an external debt share in line with that observed over the calibration period (about 26 percent of annual output). In contrast to the baseline calibration, under the present calibration the intertemporal elasticity of substitution, $1/\sigma$, exceeds the intratemporal elasticity, ξ. As a consequence and as suggested in section 5, the average debt to output ratio is higher in the currency peg economy than in the optimal-exchange rate economy (0.24 versus 0.14, respectively), which represents a reversal of the predictions obtained under the baseline calibration. Table 2 shows that under this alternative calibration the welfare costs of currency pegs continue to be extremely high with a median of 9.9 percent of consumption per period. This figure is slightly smaller than its baseline counterpart. This is expected because less risk averse agents are more tolerant to economic fluctuations, and because consumption is more volatile in the currency peg economy than in the optimal-exchange-rate policy economy. However, in our general disequilibrium model, the bulk of the welfare losses associated with a currency peg stems not from this second-order source but from the average unemployment induced by this type of policy, which is a first-order effect. And the high rate of unemployment induced by a currency peg appears to be robust to changes in σ. Specifically, when σ takes the value of 2, the average rate of unemployment continues to be high, above ten percent. Such a high rate of unemployment implies a permanent loss of nontradable output of about 12 percent per period, which given the weight of 0.74 of nontradable consumption in the aggregator function implies a permanent loss of total consumption of about 9 percent per period. This loss of consumption is entirely avoided under the optimal exchange rate policy because in that case the economy is always operating at full employment.

The fact that the main source of welfare losses associated with currency pegs is unemployment in the nontraded sector suggests that a key parameter determining the magnitude of these welfare losses should be γ, which governs the degree of downward nominal wage rigidity. Our baseline calibration assumes that nominal wages can fall frictionlessly by four percent per year, $\gamma = 0.99$. We now double the degree of wage flexibility by allowing nominal wages to fall costlessly by up to 8 percent per year, $\gamma = 0.98$, while keeping all other parameters of the model at their baseline values. Table 2 shows that the median welfare cost of a currency peg falls significantly from 10.4 to 6.7 percent of the consumption stream, as the degree of downward wage flexibility increases from 4% per year to 8% per year. The intuition why currency pegs are less painful when wages are more downwardly flexible is straightforward. A negative aggregate demand shock reduces the demand for nontradables which requires a fall in the real wage rate to avoid unemployment. Under a currency peg this downward adjustment must be brought about exclusively by a fall in nominal wages. The less downwardly rigid are nominal wages, the faster is the downward adjustment in both the nominal and the real wage and therefore the smaller is the resulting level of unemployment. Still, a median welfare cost of 6.7 percent of each period's consumption is an enormous figure in the context of business-cycle analysis.

8 Discussion and Conclusion

In this paper we show that currency pegs can be extremely costly to sustain when nominal wages are downwardly rigid. The reason is that the presence of two nominal rigidities, namely a fixed exchange rate and a downwardly sticky nominal wage, results in a real rigidity. In the context of our model, this real rigidity takes the form of downward sluggish adjustment of the real wage expressed in terms of tradables. In turn, the sluggish downward adjustment in the real wage makes the labor market vulnerable to large unemployment spills when the economy suffers adverse external shocks such as increases in the country interest rate premium or deteriorations in its terms of trade.

We develop a novel dynamic stochastic disequilibrium model of a small open economy that captures well the real affects of the aforementioned dual nominal rigidity. We then quantify the real effects and welfare consequences of a currency peg in the context of our disequilibrium model. To this end, we estimate the driving forces of the model using data from a small emerging economy. We then feed these processes into our disequilibrium model, which allows us to characterize the macroeconomic dynamics implied by a currency peg. We find that a large external shock, defined as a two-standard-deviation collapse in the value of tradable output, causes massive unemployment of about 20 percent of the labor force. This figure is consistent with the unemployment 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 (e.g., Latvia, Greece, Portugal, Spain, and Ireland) post 2008. Furthermore, we find that under a currency peg unemployment is highly persistent. Our model predicts that even five years after the trough of the crisis the unemployment rate remains above 8 percent.

We contrast the behavior of the economy under a currency peg to that under the optimal exchange rate policy. We show that the optimal exchange rate policy completely eliminates the real effects of nominal downward wage rigidities. In particular, the optimal policy is able to bring about full employment of the labor force at all times. An important feature of the optimal exchange rate policy is that during an external crisis of the type described above the central bank engages in a series of large devaluations of the domestic currency. These devaluations are aimed at lowering the real value of the downwardly rigid nominal wage to a level consistent with full employment. Interestingly, these devaluations occur in the context of a severe contraction of economic activity and domestic spending driven by adverse shocks in the traded sector. As a result, under optimal exchange rate policy, the model predicts a positive correlations between the rate of devaluation and economic crisis. This pattern of correlation could lead non-structural econometric analysis to wrongly conclude that devaluations are contractionary. The reason that such a conclusion would be misplaced is that under optimal exchange-rate policy devaluations prevent economic crises originating in the traded sector from spreading to the non-traded sector, that is, absent a devaluation the recession caused by the negative external shock would be more severe. We therefore conclude that in the context of our model devaluations are not contractionary but rather contractions are ‘devaluatory.’

Our quantitative model allows us to address the question of how costly currency pegs are in terms of welfare. We find that these costs are enormous. At the median of the distribution of welfare costs, households living under a currency peg require a ten percent increase in consumption every period to be as well off as households living in an economy in which the central bank implements the optimal exchange-rate policy. The source of these large welfare costs is twofold. First, as mentioned earlier, currency pegs entail high levels of unemployment which affects negatively the supply and ultimately the domestic absorption of nontradable goods. Second, the malfunctioning of the price system under a currency peg implies that the real exchange rate fails to depreciate sufficiently during an external crisis, which hinders the necessary domestic expenditure switch away from tradables toward nontradables. As a result, the currency peg economy takes on more external debt during a crisis than does the optimal-exchange-rate economy. This results in a much wider distribution of external debt under a currency peg. For such behavior of external debt to be sustainable in the long run, the currency-peg economy must hold less external debt on average than the optimal exchange-rate economy. Thus, a switch from a currency peg to the optimal exchange-rate policy allows households to draw down their precautionary savings via a temporarily higher level of traded consumption, which is welfare increasing. We find that the welfare costs of currency pegs are larger than its median of ten percent when the initial state of the economy is characterized by weak fundamentals such as high external debt, high past real wages, high country premia, or weak terms of trade. These findings shed light on why pressures to abandon the currency peg emerged with force in Argentina in 2001 and across the emerging-market members of the European Union in the wake of the great contraction of 2008. Besides being on a fixed exchange rate, these countries had in common high country premia, high levels of external debt, weak terms of trade, and a highly unionized labor force that all but prevented nominal wage cuts.

Many observers have suggested the use of fiscal policy to ease the pains of currency pegs currently felt in the periphery of the European Union. However, advocates of active fiscal policy do not speak with a single voice. Some argue that the right medicine for emerging country members of the European Union 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. Specifically, optimal fiscal policy in the context of a currency peg consists in a time-varying labor income subsidy that targets industries with high degrees of downward wage rigidity. It can be shown that in our currency-peg economy the full-employment equilibrium can be reached by implementing a proportional wage subsidy at the rate τ_t, where

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

where $\omega(c_t^T)$ denotes the flexible-wage real wage and γw_{t-1} denotes the real wage that prevails when the wage rigidity is binding. If the combination of the currency peg and the downward nominal wage rigidity prevent the real wage from falling to the flexible-wage real wage, the subsidy is positive. Because $\omega(c_t^T)$ is strictly increasing in the domestic absorption of tradables, it follows that the labor subsidy will be positive only in periods in which domestic absorption of tradables is depressed.

In our view the implementation of this optimal subsidy would be politically problematic in small emerging countries of the European Union for at least two reasons. First, because the subsidy is countercyclical, it contributes to fiscal deficits during downturns which runs against the recommendation of the European Commission. Second, the optimal subsidy must be largest in nontraded sectors in which downward nominal wage rigidity is most prevalent. To the extend that downward wage rigidities and the degree of unionization are positively correlated, this subsidy would be viewed as favoring more unionized sectors at the expense of more competitive ones. Curiously, a subsidy of this type was implemented in Germany in the wake of the 2008 global crisis under the name 'Kurzarbeit' to combat unemployment. This raises the question of why a countercyclical labor subsidy was politically viable in large country like Germany. We believe that Germany being a large economy had more autonomy in setting its fiscal deficit. In addtion, eventhough Germany has a highly unionized labor force, the degree of unionization is quite homogeneous across industries. As a result 'Kurzarbeit' will not appear as favoring less competitive sectors.

In closing this discussion, we wish to stress that our analysis does not explicitly incorporate the potential benefits of a fixed-exchange-rate arrangement. The benefits mostly stem from facilitating transactions across borders. For instance, firms located in different countries of the currency union can write commercial contracts without worrying about exchange rate risk. Also, consumers can travel within the currency union without having to pay the transaction costs associated with currency exchange. We therefore interpret the results of this paper as suggesting that the survival of the European currency union over time without major structural reforms would provide indirect evidence that the sum of the pecuniary and non-pecuniary benefits of a single currency outweigh the large welfare costs identified in our analysis. Otherwise, if the welfare costs of a currency union exceed its benefits, survival of the currency union would require major structural reforms. One such reform that is strongly suggested by our analysis is the enhancement of labor market flexibility. In this vein, an important topic for future research would be a historical comparison of the degree of labor market flexibilty at the time of adoption of a common currency in the United States and Europe and the contribution of this factor to the longevity of the exchange rate arrangement.

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