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PEGS, DOWNWARD WAGE RIGIDITY, AND UNEMPLOYMENT:
THE ROLE OF FINANCIAL STRUCTURE

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ABSTRACT

This paper studies the relationship between financial structure and the welfare consequences of fixed exchange rate regimes in small open emerging economies with downward nominal wage rigidity. The paper presents two surprising results. First, a pegging economy might be better off with a closed than with an open capital account. Second, the welfare gain from switching from a peg to the optimal (full-employment) monetary policy might be larger in financially open economies than in financially closed ones.

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1 Introduction

A characteristic of the current European crisis is that countries in its periphery have found themselves increasingly cut off from international financial markets. In the present study, we ask how such changes in the financial structure influence the welfare consequences of maintaining a fixed exchange rate regime. We address this issue in the context of a dynamic model of an emerging economy with involuntary unemployment developed in Schmitt-Grohé and Uribe (2011).

In that model negative external shocks lead to involuntary unemployment because of the combination of downward nominal wage rigidity and a currency peg. The mechanism is as follows. Consider the economy's adjustment to a negative tradable output shock, such as a deterioration in the terms of trade. Households respond to this negative external shock by lowering their demand for consumption goods. In the nontraded sector, the decline in aggregate demand causes the relative price of nontradables to fall. In turn, firms face lower prices but unchanged costs. The reason why costs are unchanged is that nominal wages are downwardly rigid and the exchange rate is pegged, so that real wages expressed in terms of tradables are unable to fall. As a result firms demand fewer hours of labor. The resulting underemployment is involuntary because at the going wage rate workers would prefer to work longer hours. As shown in Schmitt-Grohé and Uribe (2011), in this environment the optimal exchange rate policy brings about full employment at all times. It does so by depreciating the value of the domestic currency during periods of low aggregate demand. The resulting real allocation is Pareto optimal. Elsewhere (Schmitt Grohé and Uribe, 2012) we show that in this model currency pegs create a pecuniary externality. The nature of the externality is that agents fail to internalize that high current absorption of tradables drives up real wages, which, once the expansion is over, fall only sluggishly (due to nominal rigidities) causing underemployment along the way.

The contribution of the present paper is to show that the aforementioned externality gives rise to two paradoxical results. The first one is that a country with a fixed exchange rate regime might enjoy higher welfare under financial autarky than when it has access to an internationally traded risk-free bond. In a version of the model calibrated to match salient features of the Argentine economy, we find that the fixed-exchange rate economy with access to an international bond requires an increase in total consumption of two thirds of one percent every period to be as well off as a fixed-exchange rate economy in financial autarky.

The second paradoxical result is that the welfare cost of pegging the currency may be larger in financially open economies than in financially closed ones. This finding suggests that the pressure on central banks to abandon a currency peg in favor of optimal exchange-rate

policy may be larger in the absence of capital controls.

The remainder of the paper is organized in five sections. Section 2 presents the model of a small open economy with involuntary unemployment due to downward nominal wage rigidity originally developed in Schmitt-Grohé and Uribe (2011). Section 3 characterizes welfare under the optimal exchange rate policy and under a currency peg in a financially autarkic economy. Section 4 introduces an internationally-traded, risk-free bond and shows that in this environment the welfare costs of currency pegs may be higher than under financial autarky. Section 5 shows that peggers may be better off in a financially closed economy. Section 6 concludes.

2 The Model

Our theoretical framework builds on Schmitt-Grohé and Uribe (2011). The model is one of a small open economy in which nominal wages are downwardly rigid, giving rise to an occasionally binding constraint. The labor market is assumed to be 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 supply of traded goods.

2.1 Households

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

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

where c_t denotes consumption, U is a utility index assumed to be increasing and strictly concave and to satisfy $\lim_{c \rightarrow 0} U'(c) = \infty$ and $\lim_{c \rightarrow \infty} U'(c) = 0$. The parameter $\beta \in (0, 1)$ 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 technology

$$c_t = A(c_t^T, c_t^N), \quad (2)$$

where c_t^T denotes consumption of tradables, c_t^N denotes consumption of nontradables, and A , defined over positive values of both of its arguments, denotes an aggregator function assumed

to be homogeneous of degree one, increasing, concave, and to satisfy the Inada conditions. These assumptions imply that 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.¹ 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. The household's sequential budget constraint in period t is given by

$$c_t^T + p_t c_t^N + d_t = y_t^T + w_t h_t + \mathbb{E}_t q_{t,t+1}^* d_{t+1} + \phi_t, \quad (3)$$

where p_t denotes the relative price of nontradables in terms of tradables in period t and w_t denotes the real wage rate in terms of tradables in period t . The variable d_{t+1} is a state-contingent payment of the household to its international creditors chosen in period t . The random variable d_{t+1} can take on positive or negative values. A positive value of d_{t+1} in a particular state of period $t + 1$ can be interpreted as the external debt due in that state and date. The variable $q_{t,t+1}^*$ denotes the period- t price of an asset that pays one unit of tradable good in one particular state of period $t + 1$ divided by the probability of occurrence of that particular state conditional upon information available in period t . It follows that $\mathbb{E}_t q_{t,t+1}^* d_{t+1}$ is the period- t price of the state-contingent payment d_{t+1} . The household faces a borrowing limit of the form

$$\lim_{j \rightarrow \infty} \mathbb{E}_t q_{t,t+j}^* d_{t+j} \leq 0, \quad (4)$$

which prevents Ponzi schemes, where $q_{t,t+j}^* \equiv \prod_{s=1}^j q_{t+s-1,t+s}^*$, for $j \geq 1$.

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 denote the Lagrange multiplier associated with (3), the optimality conditions associated with this dynamic maximization problem are (2), (3), (4) holding with equality, and

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

$$\lambda_t = U'(c_t) A_1(c_t^T, c_t^N), \quad (6)$$

$$\lambda_t q_{t,t+1}^* = \beta \lambda_{t+1}, \quad (7)$$

¹In Schmitt-Grohé and Uribe (2011), we consider the case of an endogenous labor supply.

where A_i denotes the partial derivative of A with respect to its i -th argument.

Optimality condition (5) can be interpreted as a demand function for nontradables. Intuitively, it states that an increase in the relative price of nontradables induces households to engage in expenditure switching by consuming relatively less nontradables. Our maintained assumptions regarding the form of the aggregator function A guarantee that, for a given level of c_t^T , the left-hand side of this expression is a decreasing function of c_t^N . Optimality condition (7) equates the marginal benefits and the marginal costs of purchasing one-step-ahead contingent claims denominated in tradable goods.

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

$$p_t F'(h_t) = w_t. \tag{8}$$

This first-order condition implicitly defines the firm's demand for labor.

2.3 Downward Nominal Wage Rigidity

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

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

Nominal wages are assumed to be downwardly rigid. Specifically, we impose that

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

The presence of nominal wage rigidity implies the following restriction on the dynamics of real wages:

$$w_t \geq \gamma \frac{w_{t-1}}{\epsilon_t}, \quad (9)$$

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 underemployment, given by $\bar{h} - h_t$, may be a regular feature of this economy. Actual employment must satisfy

$$h_t \leq \bar{h} \quad (10)$$

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

$$(\bar{h} - h_t) \left(w_t - \gamma \frac{w_{t-1}}{\epsilon_t} \right) = 0. \quad (11)$$

This condition states that periods of unemployment must be accompanied by a binding wage constraint. It also states that when the wage constraint is not binding, the economy must be at full employment.

2.4 Market Clearing

Market clearing in the nontraded sector requires that

$$c_t^N = F(h_t). \quad (12)$$

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

$$c_t^T + d_t = y_t^T + \mathbb{E}_t q_{t,t+1}^* d_{t+1}. \quad (13)$$

It remains to specify the asset-market structure and the monetary-policy regime. In the following sections, we consider several variants of these two key features of the economic environment.

3 The Welfare Costs of Pegs Under Financial Autarky

We now study the role of exchange rate policy in an environment of financial autarky. To this end, we assume that households are cut off from international capital markets. Because the capital account is closed, consumption of tradables must equal tradable output at all times. As result, the market clearing condition (13) collapses to

$$c_t^T = y_t^T. \quad (14)$$

This condition makes it clear that under financial autarky, consumption of tradables inherits all of the volatility present in tradable output. More importantly for the purpose of our investigation, as we are about to show, because nominal wages are downwardly rigid, swings in the absorption of tradable goods can potentially spill over to the nontraded sector. While the monetary authority can do nothing about the volatility in traded consumption, it can, through appropriate policies, keep those fluctuations from causing unemployment in the nontraded sector. Thus, under financial autarky, monetary policy becomes responsible for ensuring full employment.

The following definition presents the set of conditions governing aggregate dynamics under financial autarky.

Definition 1 (General Disequilibrium Dynamics Under Financial Autarky) *Under financial autarky, aggregate dynamics are given by stochastic processes c_t , c_t^T , c_t^N , h_t , p_t , and w_t satisfying (2), (5), (8)-(12), and (14), given the exogenous stochastic process y_t^T , an exchange rate policy, and the initial condition w_{-1} .*

It will prove convenient to define the full-employment real wage in any period t , given a certain level of tradable consumption c_t^T . We denote this variable by $\Omega(c_t^T)$. From equation (8), we have that $\Omega(c_t^T)$ is formally defined as

$$\Omega(c_t^T) \equiv \frac{A_2(c_t^T, F(\bar{h}))}{A_1(c_t^T, F(\bar{h}))} F'(\bar{h}). \quad (15)$$

The assumptions made on the form of the aggregator A guarantee that $\Omega(c_t^T)$ is strictly increasing in c_t^T . The intuition for why the full-employment real wage is increasing in consumption of tradables is as follows. Given the relative price of nontradables, an increased desire to consume tradable goods is accompanied by an increased demand for nontradables. In turn, the elevated demand for nontradables pushes the relative price of these goods upward, creating an incentive for entrepreneurs to hire more labor. However, because the economy is already at full employment in the nontraded sector, the increased demand for

labor causes the real wage to rise to a level at which the quantity of hours demanded by firms equals the full-employment level \bar{h} .

We are now ready to formally characterize optimal exchange-rate policy under financial autarky.

Proposition 1 (Optimal Exchange-Rate Policy Under Financial Autarky) *Suppose that the economy is in perpetual financial autarky. Then, $h_t = \bar{h}$ and the real allocation is Pareto optimal if and only if the exchange-rate regime satisfies*

$$\epsilon_t \geq \gamma \frac{w_{t-1}}{\Omega(y_t^T)}, \quad (16)$$

for all $t \geq 0$.

Proof. Suppose that the economy is in financial autarky ($c_t^T = y_t^T$) and that $\epsilon_t \geq \gamma \frac{w_{t-1}}{\Omega(y_t^T)}$. Assume that $h_t < \bar{h}$ for some $t \geq 0$. Then, by the slackness condition (11) we have that $w_t = \gamma \frac{w_{t-1}}{\epsilon_t}$. Combining this expression with $\epsilon_t \geq \gamma \frac{w_{t-1}}{\Omega(y_t^T)}$ yields $w_t \leq \Omega(y_t^T)$. Finally, using (8) and (15) to get rid of w_t and $\Omega(y_t^T)$, respectively, we obtain $\frac{A_2(y_t^T, F(h_t))}{A_1(y_t^T, F(h_t))} F'(h_t) \leq \frac{A_2(y_t^T, F(\bar{h}))}{A_1(y_t^T, F(\bar{h}))} F'(\bar{h})$. But this is a contradiction, because the left-hand side of this inequality is strictly decreasing in h_t and because $h_t < \bar{h}$. Therefore, h_t must equal \bar{h} at all times, as claimed. Now suppose that the economy is in financial autarky and that $h_t = \bar{h}$ for all $t \geq 0$. It follows from (8) and (15) that $w_t = \Omega(y_t^T)$. Combining this expression with (9) yields $\epsilon_t \geq \gamma \frac{w_{t-1}}{\Omega(y_t^T)}$, as claimed. To see that the full-employment allocation is Pareto optimal, simply note that the processes $h_t = \bar{h}$ and $c_t^T = y_t^T$ for all t represent the solution to the problem of maximizing (1), subject to (2), (10), (12), and (14), which is the optimization problem of a social planner who is not constrained by downward nominal wage rigidity. ■

It follows from proposition 1 that when the economy is in financial autarky, the optimal exchange-rate policy calls for a devaluation whenever the economy experiences a sufficiently large negative tradable-endowment shock. To see this more transparently, replace w_{t-1} for $\Omega(y_{t-1}^T)$ in equation (16) to obtain

$$\epsilon_t \geq \gamma \frac{\Omega(y_{t-1}^T)}{\Omega(y_t^T)}; \quad t > 0.$$

Since Ω is strictly increasing, we have that $\epsilon_t > 1$ when y_t^T falls sufficiently below y_{t-1}^T . The intuition behind this result is as follows: In response to a fall in tradable output, all other things equal, households feel poorer, and, as a consequence, reduce their demands for both tradable and nontradable goods. The contraction in the demand for the nontraded good

depresses its relative price, which in turn induces firms to cut supply. This causes a fall in the aggregate demand for labor. Full employment, therefore, requires a reduction in the real wage, W_t/E_t . Because the nominal wage, W_t , is downwardly rigid, however, the required decline in the real wage must be brought about via a depreciation of the domestic currency, i.e., via an increase in E_t .

Should the central bank fail to devalue the domestic currency in a situation of depressed demand for tradables like the one described in the previous paragraph, unemployment would ensue. In this case, a negative shock that originates in the traded sector would spread to the nontraded sector. It follows immediately that a currency peg, defined as an exchange-rate policy that sets $\epsilon_t = 1$ at all times, is in general not optimal under financial autarky. We formalize this result in the following corollary:

Corollary 1 (Nonoptimality of Currency Pegs Under Financial Autarky) *Suppose that the economy is in financial autarky. Then, in general, the exchange-rate policy*

$$\epsilon_t = 1$$

for all $t \geq 0$ does not implement the Pareto optimal allocation.

A natural question is how far the allocation induced by a currency peg is from the Pareto optimal allocation. One way to measure this distance, is to gauge how costly it is in terms of welfare to adhere to a currency peg as opposed to following the optimal exchange rate policy. This question is essentially quantitative. For this reason, we resort to numerical simulations. Specifically, using a calibrated version of the model, we compare the levels of welfare associated with the optimal exchange-rate policy and with a currency peg.

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

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

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

and

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

We calibrate the model at a quarterly frequency. All parameter values are taken from Schmitt-Grohé and Uribe (2011) and are shown in table 1. A novel parameter in our model is γ , governing the degree of downward nominal wage rigidity. In Schmitt-Grohé and Uribe

Table 1: Calibration

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

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

(2011), we present empirical evidence on the size of this parameter. This evidence suggests that nominal wages are downwardly rigid but not upwardly and that a realistic value of γ is close to unity. We set $\gamma = 0.99$, which is conservative, in the sense that the empirical evidence analyzed points to values greater than 0.99. For instance, Schmitt-Grohé and Uribe (2011) analyze data on unemployment and nominal wage growth in ten peripheral European countries that are either on the Euro or pegging to it over the period 2008:Q1 and 2011:Q2. They show that unemployment increased in all ten countries during this period. At the same time, nominal hourly wages fell in only three countries and by a maximum of 5.1 percent over the 13 quarters considered. This means that the smallest implied value of γ in this sample is 0.996. Our calibrated value of 0.99 implies that over the 13 quarters considered nominal wages could have fallen by 13 percent, which is more than twice the maximum observed wage decline. This is the precise sense in which we argue that our choice of γ allows for more downward wage flexibility than observed in the recent European crisis.²

We also borrow from earlier work (Schmitt-Grohé and Uribe, 2011) the stochastic process driving aggregate fluctuations in our economy. Specifically, we assume that tradable output and the country interest rate, denoted r_t , follow a bivariate, first-order, autoregressive process of the form

$$\begin{bmatrix} \ln y_t^T \\ \ln \frac{1+r_t}{1+r} \end{bmatrix} = A \begin{bmatrix} \ln y_{t-1}^T \\ \ln \frac{1+r_{t-1}}{1+r} \end{bmatrix} + \nu_t, \quad (17)$$

where ν_t is a white noise of order 2 by 1 distributed $N(\emptyset, \Sigma_\nu)$. The parameter r denotes

²This calculation assumes that the nominal price of tradables abroad, P_t^{T*} , is constant. But our calibration of γ continues to be conservative even if we allow for a realistic value for foreign inflation. Over the 13-quarter period in question, the German CPI index grew by a cumulative of 3.7 percent. Combining this figure with the maximum observed wage decline of 5.1 percent, yields 8.8, which is still significantly smaller than the 13 percent decline in nominal wages allowed by our calibration.

the deterministic steady-state value of r_t . The country interest rate r_t represents the rate at which the country could borrow in international markets if it was open to capital flows. In the present autarkic economy, the country interest rate plays no role other than helping forecast tradable output. In the next section, we will consider an economy with access to international financial markets, in which r_t will govern the costs of external funds. In Schmitt-Grohé and Uribe (2011), we estimate the system (17) using Argentine data over the period 1983:Q1 to 2001:Q4. Our OLS estimates of the matrices A and Σ_ν and of the scalar r are

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

We discretize the AR(1) process given in equation (17) using 21 equally spaced points for $\ln y_t^T$ and 11 equally spaced points for $\ln(1+r_t)/(1+r)$. For details, see Schmitt-Grohé and Uribe (2011).

We numerically approximate the lifetime utility of the representative household under the optimal exchange rate policy by applying the method of value function iteration over a discretized state space. Under optimal exchange rate policy, the state of the economy in period $t \geq 0$ is the exogenous variable y_t^T . The welfare of the representative household under the optimal exchange rate policy can be approximated by solving the following simple Bellman equation

$$v^{AUT,OPT}(y_t^T) = U(A(y_t^T, F(\bar{h}))) + \beta \mathbb{E}_t v^{AUT,OPT}(y_{t+1}^T),$$

where $v^{AUT,OPT}$ denotes the value function of the representative household under autarky and optimal exchange-rate policy.

Approximating the dynamics of the model under a currency peg is computationally more demanding than doing so under optimal exchange rate policy. The reason is that aggregate dynamics can no longer be cast in terms of a Bellman equation, because of the distortions introduced by nominal rigidities. We therefore approximate the solution by policy function iteration over a discretized version of the state space (y_t^T, w_{t-1}) . An additional source of complication is the emergence of a second state variable, w_{t-1} , which, unlike y_t^T , is endogenous. For the discretization of w_{t-1} we use 500 equally spaced points for its logarithm.

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. Specifically, one can express the value function associated

Table 2: Welfare Costs of Currency Pegs

Financial Structure	Welfare Cost (mean)	Unemployment				$\Delta(\ln(w_t))$	Devaluation	
		Mean		Std. Dev.		Std. Dev.	Mean	
		Opt.	Peg	Opt.	Peg	Opt.	Opt.	Peg
Autarky, $d_t = 0$	6.5	0.0	9.0	0.0	8.0	9.2	10.5	–
One-Bond Economy	12.3	0.0	14.5	0.0	12.0	18.1	17.4	–

Note. The welfare cost of a peg is calculated as the percentage increase in the entire consumption path associated with a peg required to yield the same level of welfare as the optimal monetary policy. The unemployment rate is expressed in percent. The standard deviation of the log change in real wages is in percent. The mean devaluation rate is in percent with the mean taken over periods in which $\epsilon_t > 1$.

with a currency-peg as

$$v^{AUT,PEG}(y_t^T, w_{t-1}) = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \frac{\left(c_{t+s}^{AUT,PEG}\right)^{1-\sigma} - 1}{1 - \sigma},$$

where $c_t^{AUT,PEG}$ denotes the stochastic process of consumption of the composite good in the currency-peg economy, given the initial state (y_t^T, w_{t-1}) . Define the proportional compensation rate $\lambda^{PEG|AUT}(y_t^T, w_{t-1})$ implicitly as

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \frac{\left[c_{t+s}^{AUT,PEG}(1 + \lambda^{PEG|AUT}(y_t^T, w_{t-1}))\right]^{1-\sigma} - 1}{1 - \sigma} = v^{AUT,OPT}(y_t^T).$$

Solving for $\lambda^{PEG|AUT}(y_t^T, w_{t-1})$, we obtain

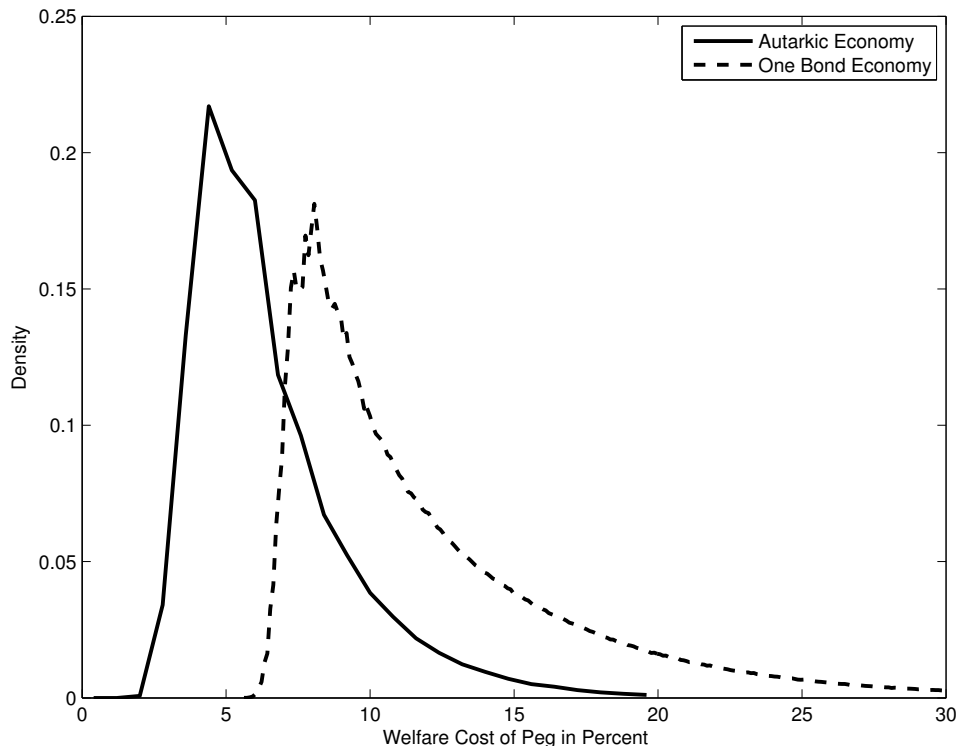
$$\lambda^{PEG|AUT}(y_t^T, w_{t-1}) = \left[\frac{v^{AUT,OPT}(y_t^T)(1 - \sigma) + (1 - \beta)^{-1}}{v^{AUT,PEG}(y_t^T, w_{t-1})(1 - \sigma) + (1 - \beta)^{-1}} \right]^{1/(1-\sigma)} - 1.$$

This expression makes it clear that the compensation $\lambda^{PEG|AUT}(y_t^T, w_{t-1})$ is state dependent. We compute the probability density function of $\lambda^{PEG|AUT}(y_t^T, w_{t-1})$ by sampling from the ergodic distribution of the state (y_t^T, w_{t-1}) under the currency peg.

We find that when financial markets are closed, the welfare losses due to suboptimal monetary policy can be large for countries facing large external shocks. Table 2 shows that the mean welfare cost of a currency peg relative to the optimal policy is 6.5 percent of consumption each period.³ Figure 1 displays with a solid line the density function of the

³This number falls to 4.1 percent when γ is lowered to 0.98. This is still a large number as welfare costs

Figure 1: Probability Density Function of the Welfare Cost of Currency Pegs



welfare cost of pegs under autarky. The support of this density ranges from a minimum of 1.8 percent to a maximum above 20 percent. These are extremely large numbers as welfare costs of suboptimal policy go in Macroeconomics, and suggests that monetary policy can play an important role in moderating the negative effects of adverse external shocks. The root of these large welfare losses is that a currency peg causes unemployment of 9 percent of the labor force on average. By contrast, unemployment is nil at all times under the optimal monetary policy. The key difference between the optimal monetary policy and the currency peg is that the former allows for reductions in the real wage in periods of weak aggregate demand. The standard deviation of real wage changes under the optimal exchange-rate policy is significant, 9.2 percent. Recall that these real wage changes are the ones that would occur in an flexible-wage economy. The optimal policy engineers efficient reductions in real wages during recessions by means of appropriate devaluations of the domestic currency. We find that these devaluations are large. The minimum devaluation rate compatible with full

of stabilization policy go. Relating this value of γ to the empirical evidence from the periphery of Europe discussed earlier, we have for a calibration of γ of 0.98, the model would allow nominal wages to fall by 26 percent during the period 2008:Q1 to 2011:Q2, which is five times larger than the largest observed decline in nominal wages.

employment is 10.5 percent on average.⁴ By contrast, a currency peg in combination with downward nominal wage rigidity prevents the downward adjustment of real wages during contractions, causing massive unemployment.

The rate of unemployment is highly volatile under a currency peg, with a standard deviation of 8.0 percentage points. In turn, the high volatility of unemployment implies a highly volatile supply and consumption of nontradable goods. As result, total consumption is also more volatile under a currency peg than under the optimal policy. The standard deviation of $\ln(c_t)$, not shown in the table, more than doubles from 3.2 percent under the optimal policy to 7.3 percent under a currency peg.

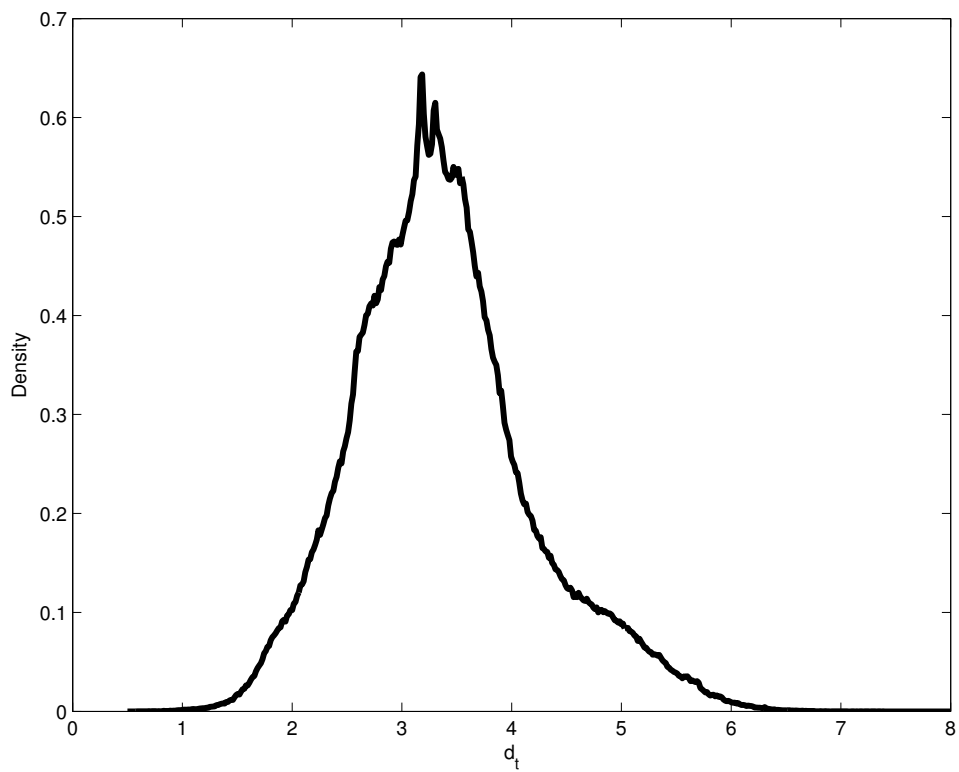
4 Do More Complete Markets Ameliorate the Costs of Pegs?

Thus far, we have established that for the type of shocks considered in our model suboptimal exchange-rate policy has large negative welfare consequences under financial autarky, posing great policy challenges to central banks in emerging countries. It would be natural to conjecture that these challenges would become more manageable the more complete asset markets are. In this section we show that this conjecture need not hold. We find that the welfare cost of a currency peg can be higher when financial markets are open than when they are closed. This result implies that central banks that peg their currencies have greater incentives to abandon the fixed-exchange-rate regime in favor of the optimal exchange rate policy when the economy is open to international capital flows than when it is financially closed.

The intuition behind this result has to do with two opposing forces determining the welfare costs of currency pegs, to which we refer as the consumption smoothing versus consumption level tradeoff. One force is the increased ability of financially open economies to insure against tradable endowment shocks. This force tends to reduce the cost of pegs because it reduces the extent to which negative endowment shocks in the traded sector, through their contractionary effects on aggregate absorption, lead to unemployment in the nontraded sector under currency pegs. The second force is that the average level of external debt is higher in the economy with access to financial markets (see figure 2). As we will explain shortly, the higher the level of debt, the larger the welfare cost associated with a peg, because the level of external debt amplifies the volatility of real-wage changes, making nominal rigidities bind more often. When the second force dominates the first (i.e., when the

⁴The minimum devaluation rate compatible with full employment is given by $\epsilon_t = \gamma w_{t-1} / \Omega(y_t^T)$. For the present calibration, $\mathbb{E}(\epsilon_t | \epsilon_t > 1) = 1.105$, or 10.5 percent, which is the number given in the text.

Figure 2: The Distribution of External Debt in the One-Bond Economy under a Currency Peg



consumption level effect dominates the consumption smoothing effect), the counterintuitive result obtains, namely that a currency peg is more costly vis-à-vis the optimal exchange-rate policy when financial markets are open than when they are closed.

We make asset markets more complete than under autarky by introducing a one-period bond denominated in terms of tradables that is traded internationally and carries an interest rate r_t when held from period t to $t+1$. We assume full dollarization of households' liabilities, because this is arguably the case of greatest empirical interest in emerging countries. Under this financial market structure, market clearing in the traded sector becomes

$$c_t^T + d_t = y_t^T + \frac{d_{t+1}}{1 + r_t} \quad (18)$$

and

$$d_{t+1} \leq \bar{d}. \quad (19)$$

Equation (19) is a borrowing limit that prevents agents from engaging in Ponzi schemes. We set the parameter \bar{d} at the natural debt limit.

The following definition gives the set of conditions governing aggregate dynamics under this asset market structure.

Definition 2 (General Disequilibrium Dynamics in the One-Bond Economy) *General disequilibrium dynamics in the one-bond economy are given by stochastic processes c_t , c_t^T , c_t^N , h_t , p_t , d_{t+1} and w_t for $t \geq 0$, satisfying (2), (5), (8)-(12), (18), and (19), given the exogenous stochastic processes y_t^T , r_t , an exchange rate policy, and the initial conditions d_0 , and w_{-1} .*

As before, we consider two exchange rate regimes. One is a currency peg, $\epsilon_t = 1 \quad \forall t \geq 0$, and the other is the optimal exchange rate policy. The family of optimal exchange-rate policies in the one-bond economy is identical to the one derived in the autarkic economy (see Proposition 1), except that y_t^T is replaced by c_t^T as the argument of the function Ω in equation (16). We therefore have the following proposition

Proposition 2 (Optimal Exchange-Rate Policy in the One-Bond Economy) *Consider an economy satisfying definition 2. Then, h_t equals \bar{h} for all t and the real allocation is Pareto optimal if and only if the exchange-rate regime satisfies*

$$\epsilon_t \geq \gamma \frac{w_{t-1}}{\Omega(c_t^T)}, \quad (20)$$

for all $t \geq 0$.

Proof. The proof is analogous the proof of Proposition 1. ■

As in the case of financial autarky, we approximate aggregate dynamics by discretizing the state space and applying the method of value function iteration in the case of optimal exchange-rate policy and the method of policy function iteration in the case of a fixed-exchange-rate policy. The numerical problem is now more complex due to the emergence of two additional state variables: the endogenous state d_t and the exogenous state r_t . We use 501 equally spaced points to discretize the debt subspace.

An important difference between the autarkic and one-bond economies is that the latter features positive debt on average. Figure 2 displays the unconditional distribution of external debt in the one-bond economy when exchange-rate policy takes the form of an exchange-rate peg. The mean external debt is 3.38, or 26 percent of annual output. The average level of debt in the present environment is determined to a large extent by the assumption that agents are impatient (note that $\beta(1 + \mathbb{E}r_t)$ is less than unity) and by aggregate uncertainty.⁵ Impatience induces agents to choose debt levels near the natural limit, \bar{d} , whereas uncertainty gives an incentive for precautionary savings and, therefore, for keeping debt below the natural limit.

As in the case of financial autarky, we define the welfare cost of a currency peg vis-à-vis the optimal exchange-rate policy as the percent increase in the consumption stream induced by a currency peg that makes households as well off as households living in the optimal-exchange-rate economy. Formally, letting $\lambda^{PEG|BOND}(y_t^T, r_t, d_t, w_{t-1})$ denote the welfare cost of a currency peg relative to the optimal exchange-rate-policy in the one-bond economy, we have that

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

where $v^{BOND,OPT}(y_t^T, r_t, d_t)$ and $v^{BOND,PEG}(y_t^T, r_t, d_t, w_{t-1})$ denote, respectively, the value function of the representative household under the optimal exchange-rate policy and under a currency peg in the one-bond economy.

Table 2 shows that the mean welfare cost of a currency peg relative to the optimal exchange rate policy, $\mathbb{E}\lambda^{PEG|BOND}(y_t^T, r_t, d_t, w_{t-1})$, is 12.3 percent. That is, households would require a permanent increase in consumption of 12.3 percent to not have incentives to put pressure on their central bank to abandon the peg. This large welfare cost stems from the fact that the average unemployment rate in the currency-peg economy is 14.5 percent. The

⁵The subjective discount factor was calibrated to ensure a debt-to-output ratio of 26 percent per year, which is the one observed in Argentina between 1983 and 2001. See Schmitt-Grohé and Uribe (2011) for more details.

Table 3: Financial Structure and the Welfare Costs of Currency Pegs

Financial Structure	Welfare Cost	
	$d_0 = 0$ (percent)	$d_0 = \mathbb{E}(d_t)$ (percent)
Autarkic Economy	3.7	10.0
One-Bond Economy	5.4	9.6

Note. The welfare cost of a currency peg relative to the optimal policy is computed at $y_0^T = \mathbb{E}y_t^T = 1$, $r_0 = \mathbb{E}r_t = 0.0316$, $w_{-1} = \Omega(1) = 2.13$, and at two values of d_0 , namely, zero (the autarkic level) and $\mathbb{E}d_t = 3.38$, where $\mathbb{E}d_t$ denotes the unconditional mean of debt in the one-bond economy under a currency peg. The welfare cost of a peg is calculated as the percent increase in the consumption process associated with a peg required to yield the same level of welfare as the optimal exchange-rate policy.

average cost of pegs in the one-bond economy is much larger than the 6.5 percent obtained under autarky. Indeed, as can be seen from figure 1, the entire density function of welfare costs of pegs in the one-bond economy is located to the right of the corresponding density under financial autarky.

Because the average levels of debt in the autarkic and one-bond economies are so different, comparing the relative merits of alternative exchange-rate policies across asset market structures is more meaningful at common initial values of the state vector. There are two initial conditions that are of particular interest. The first such initial condition is the one in which the level of debt equals its autarkic value of zero ($d_0 = 0$) and the second is the one in which the level of debt equals its mean in the one-bond economy under a currency peg ($d_0 = 3.38$). Accordingly, we compute the welfare cost of a currency peg for these two values of initial debt. For the remaining state variables, we set the initial levels of tradable endowment and of the real interest rate at their respective unconditional means ($y_0^T = \mathbb{E}(y_t^T) = 1$ and $r_0 = \mathbb{E}(r_t) = 0.0316$) and the initial value of the past real wage at the full-employment level when tradable consumption is unity ($w_{-1} = \Omega(1) = 2.13$).

Table 3 shows that the welfare cost of pegs are also extremely high at the initial conditions considered. In all four cases, agents in the peg economy require an increase of more than 3.5 percent of the entire consumption process to be as well off as in the optimal-exchange-rate-policy economy. A novel result of the present investigation is that the welfare cost of a currency peg relative to the optimal exchange-rate policy is larger when the economy is financially open than when it is financially closed. Specifically, table 3 shows that conditional on the initial net foreign asset position being zero ($d_0 = 0$), the welfare cost of a currency peg relative to the optimal exchange-rate policy in the autarkic economy is 3.7 percent,

almost two percentage points lower than the corresponding conditional welfare cost in the financially open economy, which is 5.4 percent.

This result is surprising because one might expect that as financial markets become more complete, agents would be able to better insure against external shocks, making suboptimal policy less harmful. The result is due to the fact that under a currency peg the average unemployment rate is larger in the one-bond economy than in the autarkic economy (14.5 versus 9.0 percent). The intuition why a peg creates more unemployment in the one-bond economy than in the closed economy is clear, but a bit involved. It has to do with the fact that the one-bond economy has on average a positive level of external debt, whereas the autarkic economy features no debt by construction. In the one-bond economy, under a currency peg, the debt-to-output ratio is 0.26 per year. This debt requires the allocation of some tradable output to paying interest. As a result, households optimally choose an average level of tradable consumption that is lower than the corresponding level in the autarkic economy (0.9 versus 1.0). This means that a given shock to the tradable endowment represents a larger share of traded consumption in the one-bond economy than in the autarkic economy. This translates into higher volatility of the growth rate of tradable consumption (5.1 percent in the one-bond economy versus 4.1 percent in the autarkic economy). Recalling that the flexible-wage real wage, $\Omega(c_t^T)$, is a function of tradable consumption alone (see equation (15)), we have that a higher variance of tradable consumption growth is associated with a higher volatility of the flexible-wage real wage growth (18.1 percent in the one-bond economy versus 9.2 percent in the autarkic economy). In turn, a higher volatility in the growth rate of the flexible-wage real wage means that under a peg the constraint on nominal wages will bind more often, which implies that the one-bond economy will experience unemployment more often than the autarkic economy. Finally, more frequent unemployment spells are welfare decreasing as they reduce the supply and consumption of nontraded goods.

Our intuition for why a currency peg is more costly in the one-bond economy than under autarky suggests that this result could be overturned if one were to define financial autarky as a situation in which the country is forced to run a balanced current account in every period—so that the level of external debt stays constant over time—but carries a debt burden equal to the average external debt in the one-bond economy with a fixed-exchange-rate policy. Under this definition of financial autarky, equation (14) becomes

$$c_t^T = y_t^T - \frac{r_t}{1 + r_t} d^a, \quad (21)$$

where d^a denotes the constant level of external debt in this version of the autarkic economy. We set d^a equal to 3.38, which, as mentioned above, is the unconditional mean of

external debt in the one-bond economy with a fixed-exchange-rate regime. This experiment amounts to eliminating the consumption-level force from the consumption-smoothing versus consumption-level tradeoff.

Table 3 shows that the welfare cost of a peg relative to the optimal exchange-rate policy conditional on the initial debt being equal to 3.38 is 9.6 percent, slightly below the welfare cost of a currency peg in the autarkic economy with external debt equal to 3.38 at all times. This result is more intuitive and is due to the fact that in the autarkic economy tradable consumption is on average lower than when debt was fixed at zero. As a result a given shock to the endowment of tradables causes a larger percent increase in tradable consumption. In addition, the autarkic economy is now hit by an additional shock, the interest rate, which adds even more volatility to the tradable consumption process.

5 Should Peggers Restrict Capital Flows?

Consider a country that is highly committed to a peg. We have in mind arrangements like the eurozone in which breaking away from the common currency appears difficult for reasons that go beyond the state of the business cycle. In this section, we investigate whether, given that the country is pegging the exchange rate, it would be desirable to restrict capital account transactions as a way to reduce the inefficiencies caused by negative external shocks.

We address this issue by considering two economies in which the currency is fixed. In one economy the capital account is closed (possibly through explicit government regulation). As in previous sections, we refer to this economy as the autarkic economy. In the second economy, the capital account is unrestricted. Households have access to an internationally traded bond. As before, we refer to this environment as the one-bond economy.

The specific question we aim to answer is whether it could be that closing the capital account is desirable. In the absence of downward nominal wage rigidity, the answer is trivially no. For given identical initial conditions, welfare must be higher in the economy with an open capital account. The result follows directly from the facts that under flexible wages the competitive equilibrium is Pareto optimal and that the autarkic allocation is feasible in the one-bond economy.

When wages are downwardly rigid, however, it is no longer the case that welfare must be higher in the financially open economy than in the closed one. The reason is that the currency peg economy with wage rigidity (whether open or closed) has a pecuniary externality. The nature of this externality has to do with the fact that, in states in which aggregate absorption contracts sufficiently, the lower bound on nominal wages binds, causing involuntary unemployment. The household understands this mechanism, but, because of its atomistic

nature, is unable to internalize the fact that its individual expenditure contributes to the generation of unemployment.

Whether agents are better or worse off in the open economy than under financial autarky is the result of a tradeoff. On the one hand, opening the current account provides households with a financial instrument to smooth consumption. On the other hand, opening the current account induces households to accumulate foreign debt, which aggravates the inefficiencies introduced by the pecuniary externality. The reason why the inefficiencies are larger the larger is the net debt position is that, as explained earlier, traded consumption is lower on average in economies with larger levels of external debt, because resources must be devoted to servicing the external obligations. This implies that external shocks have a relatively larger effect on traded consumption the larger the average level of external debt. And higher volatility of traded consumption growth causes the lower bound on nominal wages to bind more often.

We define the welfare cost of financial autarky for peggers as the percent increase in the consumption stream associated with the financially autarkic economy under a peg necessary to make households as well off as households living in the one-bond economy under a peg. Formally, let $\lambda^{AUT|PEG}(y_t^T, r_t, d_t, w_{t-1})$ denote the welfare cost of financial autarky for peggers. Then $\lambda^{AUT|PEG}(y_t^T, r_t, d_t, w_{t-1})$ is defined as the solution to

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \frac{\left[c_{t+s}^{AUT,PEG} (1 + \lambda^{AUT|PEG}(y_t^T, r_t, d_t, w_{t-1})) \right]^{1-\sigma} - 1}{1 - \sigma} = v^{BOND,PEG}(y_t^T, r_t, d_t, w_{t-1}),$$

where $c_t^{AUT,PEG}$ denotes consumption in the financially autarkic economy under a currency peg in period t , and $v^{BOND,PEG}(y_t^T, r_t, d_t, w_{t-1})$ denotes the welfare level of households living in the one-bond economy under a currency peg when the current state is $(y_t^T, r_t, d_t, w_{t-1})$. Solving for $\lambda^{AUT|PEG}(y_t^T, r_t, d_t, w_{t-1})$, we obtain

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

where $v^{AUT,PEG}(y_t^T, r_t, d_t, w_{t-1})$ denotes the level of welfare in the financially autarkic economy under a peg when the current state is $(y_t^T, r_t, d_t, w_{t-1})$.

Table 4 displays the welfare cost of financial autarky for peggers. Consider first the case in which financial autarky is taken to be a situation in which net foreign assets are zero at all times ($d_t = 0$ for all t). To make the welfare comparison meaningful, we set the initial level of foreign debt in the one-bond economy also to zero. In both economies, the initial endowment and the initial interest rate are set at their respective unconditional

Table 4: The Welfare Cost of Financial Autarky for Peggers

Initial Debt	
$d_0 = 0$	$d_0 = \mathbb{E}(d_t)$
(percent)	(percent)
-0.7	0.9

Note. The welfare cost of financial autarky relative to the one-bond economy is computed at $y_0^T = \mathbb{E}y_t^T = 1$, $r_0 = \mathbb{E}r_t = 0.0316$, $w_{-1} = \Omega(1) = 2.13$, and at two values of d_0 , namely, zero (the autarkic level) and $\mathbb{E}d_t = 3.38$, where $\mathbb{E}d_t$ denotes the unconditional mean of debt in the one-bond economy under a currency peg. The welfare cost of financial autarky for peggers is defined as the percent increase in the consumption process associated with financial autarky in a pegging economy required to yield the same level of welfare as the one enjoyed by households in the one-bond economy under a peg.

means. The initial past real wage is set at the full-employment level when traded absorption equals unity. The table reveals the surprising result that a pegging economy would be better off never opening its capital account. That is, welfare is higher under financial autarky than in the one-bond economy. And the welfare cost of liberalizing the capital account, at two thirds of one percent, is sizable. As explained above, the reason for this finding is that forcing the economy to have zero debt at all times reduces the inefficiencies introduced by the combination of downward wage rigidity and a currency peg. This benefit more than outweighs the cost of not being able to finance external shocks.

The benefit of living in autarky disappears if the country chooses to close the capital account in a situation in which its external debt is sufficiently high. To show this, we redefine autarky to mean a situation in which the current account is zero at all times, but the level of debt is positive (and constant). Equation (21) displays the country's resource constraint under this definition of autarky. In terms of the notation of that equation, we set d^a , the constant level of external debt, at 3.38, which equals the unconditional mean of debt in the one-bond economy under a peg. Table 4 shows that in this case the welfare cost of autarky is 0.9 percent of consumption. This means that a country with a significant amount of debt (26 percent of output) is worse off closing its capital account. The intuition for this result is clear. Closing the capital account when the level of external debt is high does not ameliorate the inefficiencies introduced by the combination of wage rigidity and a fixed exchange rate, but does prevent the economy from smoothing consumption through the current account.

This result suggests that if a country that is a member of a currency union, such as Greece,

defaults (bringing its external debt close to zero) but decides to stick to the currency union, it would be better off preventing its citizens from borrowing abroad. Curiously, individual agents would prefer the lifting of such capital controls. Therefore, a referendum asking people's opinion on the adoption of capital controls would fail. But society as a whole would be badly served by capital account liberalization, because of the pecuniary externality identified above. On the other hand, if the indebted economy chose to neither default nor abandon the currency union, then it would find it in its own interest to keep the current account open to allow households to smooth consumption over time.

6 Conclusion

In this paper, we study the role of financial market structure in determining the welfare consequences of currency pegs in small open emerging economies. The central friction in the theoretical framework we use in our analysis is downward nominal wage rigidity. This nominal rigidity in combination with a fixed exchange rate regime gives rise to downward rigidity in real wages. Therefore, negative external shocks, such as terms-of-trade deteriorations or increases in the country interest rate, cause involuntary unemployment, as wages fall only sluggishly to clear the labor market.

The frictions embedded in our model give rise to two surprising results. First, a pegging economy might be better off with a closed than with an open capital account. Second, the welfare gain from switching from a peg to the optimal (full-employment) exchange-rate policy might be larger in financially open economies than in financially closed ones. This finding suggests that central banks in financially open economies have greater incentives to avoid hard currency pegs.

One avenue along which the analysis presented in this paper could profitably be extended is to introduce a meaningful reason for firms to hold dollarized liabilities. Such a modification has the potential to counterbalance the expansionary effect of devaluations stressed here and in that way enhance the appeal of fixed exchange rates.

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