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Stuck on gold: Real exchange rate volatility and the rise and fall of the gold standard, 1875–1939[☆]

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ABSTRACT

Did the gold standard diminish macroeconomic volatility? Supporters thought so, critics thought not, and theory offers ambiguous messages. Hard regimes like the gold standard limit monetary shocks by tying policymakers' hands; but exchange-rate inflexibility compromises shock absorption in a world of real disturbances and nominal stickiness. A model shows how lack of flexibility affects the transmission of terms-of-trade shocks. Evidence from the late nineteenth and early twentieth century exposes a dramatic change. The classical gold standard did absorb shocks, but the interwar gold standard did not, supporting the view that the interwar gold standard was a poor regime choice.

1. Introduction

An assumption of structural change in the macroeconomy stands at the heart of some of the most influential narratives of the economic history of the early twentieth century. Massive transformations in political economy and macroeconomic policy supposedly derived from an increasing degree of inflexibility. By the late 1920s these rigidities left economies vulnerable to economic shocks under a fixed exchange-rate regime. Despite a prevailing gold standard *mentalité*, democratic pressures encouraged policymakers to react and experiment with new macroeconomic policies, provided they could break free of their ideological fetters (Polanyi 1944; Temin 1989; Eichengreen 1992; Eichengreen and Temin 2000).

Still, evidence for these kinds of structural changes is largely fragmentary and unsystematic, with samples limited by country or time period, leaving the conventional view short of support and open to criticism. This paper re-examines the question using a much larger panel dataset covering both the prewar and interwar periods. Using exogenous terms of trade shocks to obtain identification, we find signs of a structural change in open economy macroeconomic dynamics between the classical and interwar gold standard period, one consistent with rising nominal rigidities.

These questions are of more than antiquarian interest. The optimal choice of an exchange rate regime remains one of the most durable problems in international macroeconomics. The essential tradeoff facing policy makers then and now was highlighted by the Mundell–Fleming model and is central to all New Open Economy Macroeconomic (NOEM) models. On the one hand, hard pegs can provide the economy with a nominal anchor. On the other hand, a flexible exchange rate can act as a shock absorber to buffer the economy from external shocks in the presence of nominal rigidities (Obstfeld and Rogoff, 1996).

A clear illustration of how stickiness interacts with a fixed-versus-floating choice is provided in the simple classical model of Reinhart, Rogoff, and Spilimbergo (2003). We extend this approach, and it is one we think quite suited for historical analysis. Indeed, history more

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closely resembles this stylized model than does the present. Current debate ranges over the merits of hard pegs, currency boards, and dollarization at one extreme, via adjustable pegs, crawling pegs, and dirty floats, to the idealized notion of the pure float. The debate is further complicated by the extent to which countries that claim to float actually fix and by the claim that any regime other than the "corner solutions" of hard peg or pure float is unsustainable.[1] Fortunately, the past can more justifiably be reduced to the textbook fixed-floating dichotomy. Debate over exchange rate regimes a century ago was comparatively simple: to a first approximation, countries were either on the gold standard or they were floating. To be sure, there were a few vestiges of bimetallism or silver standards, but the gold standard countries by 1913 accounted for approximately 48% of countries, 67% of world GDP, and 70% of world trade.[2]

Gold had emerged as the dominant monetary regime of its time and as a robust nominal anchor. Why? The claim was made that it helped to promote international trade and investment, and the data now back it up.[3] Small wonder, then, that after the violent disruptions of World War One the world anchored again to gold in the 1920s. Unfortunately, despite its past record for stability, the reconstituted gold standard failed; it is now generally thought to have exacerbated volatility and contributed substantially to the Great Depression (Kindleberger 1973; Temin 1989; Eichengreen 1992). One measure of this increased instability that we will study in this paper is the extent of real exchange rate volatility in the world economy.

Why did an institution that had worked so well for decades become, in the 1920s, "unsafe for use" (Temin 1989, p. 10)? And what can history teach us about the present?

In this paper we study theoretically and empirically the performance of the gold standard as a shock absorber, and find that the regime performed very differently at different times. The classical gold standard did not exacerbate real exchange rate volatility and coped well with terms-of-trade shocks. The interwar gold standard did not absorb these shocks so well, at a time when these shocks turned out to be quite large, and made real exchange rate volatility worse.

2. Conventional wisdom

As we discuss below, if one wishes to claim that a fixed exchange-rate system such as the gold standard is an optimal monetary arrangement, one has to invoke an assumption of nominal (price–wage) flexibility—an assumption that underpins perhaps the most conventional explanation for why the prewar gold standard worked while the interwar gold standard failed. In this view, the gold standard was compromised as the flexibility assumed by the classical economists gave way to the stickiness emphasized by the Keynesians. But what evidence can be adduced in favor of this view? Although it is widely believed, this explanation suffers from a lack of quantitative support and studies are rare except in a handful of countries. Our paper is an attempt at a comparative analysis that looks at structural changes in the world economy in many countries both before and after World War One. We briefly discuss some of the related literature.

Several authors have noted the tendency for nominal rigidities to increase over time in developed economies, even before the twentieth century. For example, in the United States, Hanes and James (2003) find no evidence of downward nominal wage rigidity in the mid-nineteenth century. But there is evidence of some manufacturing wage rigidity beginning in the late nineteenth century, which appears to have persisted into the twentieth century; this change may have been related to changes in labor's bargaining power and was especially strong in firms that paid high wages, had high capital intensity, or were in highly concentrated industries (Gordon 1990; Allen 1992; Hanes 1993, 2000). As the structural transformation out of agriculture and into manufacturing progressed, as capital intensification proceeded in industry, and as labor's power expanded, these trends could promote greater stickiness in the economy as a whole. As long as these nominal rigidities remained minor before 1914, they would have posed less of a problem for the classical gold standard adjustment than for its interwar successor.

What about evidence from other countries? In a study using panel data for a range of countries, Basu and Taylor (1999) found a mild increase in the cyclicality of interwar real wages, as compared to other historical periods, which is consistent with the Keynesian hypothesis.[4] Bordo, Erceg, and Evans (2000) attribute part of the severity of the U.S. Great Depression to previously absent nominal rigidities. In a study of the U.S., U.K., and Germany, Bordo, Lane, and Redish (2008) find evidence that deflation was not as damaging before World War One as in the interwar period, and they suggest that a nearly vertical aggregate supply curve had become positively sloped by the 1920s as a result of increased nominal rigidities.

Of course, these studies are by no means exhaustive or definitive when it comes to assessing the evolution of macroeconomic rigidities worldwide and further research is necessary to assess the heterogeneous experiences of countries. There is also the further problem that data quality suffers the further back in time we go; for example, the definition of U.S. and U.K. consumer price indices changes substantially after World War One, an artifact that could bias the results in the literature. These and other issues still await resolution, and must also be borne in mind for the present paper.[5]

Nonetheless, according to the fragmentary evidence provided by previous studies, it appears that nominal rigidities were perhaps not entirely absent in the world economy of the late nineteenth century. But they were on the rise, and almost certainly a factor in the Great Depression where nominal wages did not fall as rapidly as prices, an observation clearly at odds with a classical flexible-price model. Indeed, the non-neutral expansionary effect of devaluations in the setting of the 1930s has been shown for a wide range of countries (Eichengreen and Sachs 1985; Campa 1990; Bernanke and Carey 1996; Obstfeld and Taylor 2004).

An increase in nominal rigidity could offer a reason to expect the interwar period to be subject to much more turbulent adjustment in the face of shocks. This ought to be manifest in many of the economy's vital signs, but our benchmark open-economy macroeconomic model would suggest that the first place to look for symptoms would be in the behavior of the real exchange rate. A major goal of this paper is to document empirically the extent to which real exchange rate behavior shifted as the world economy moved from the classical to the interwar gold standard. We now present a theoretical structure that informs our empirical design.

[1] On the merits of hard pegs, see, e.g., Calvo and Reinhart (2001) and Dornbusch (2001). On the fragility of pegs see Obstfeld and Rogoff (1995). On the debate over "corner solutions" see Fischer (2001), Frankel (1999). On misleading exchange rate regime classifications see Reinhart and Rogoff (2004), Shambaugh (2004), and Levy-Yeyati and Sturzenegger (2005). On why developing countries have a "fear of floating" see Calvo and Reinhart (2002). On flexible exchange rates as shock absorbers see Edwards and Levy-Yeyati (2005).

[2] Figures derived from Alesina, Spolaore, and Wacziarg (2000), Maddison (1995), and Meissner (2005), respectively. On the evolution of exchange rate regimes in the late nineteenth century, and particularly the gold standard, see Eichengreen (1996), Gallarotti (1995), and Meissner (2005).

[3] On the gold standard and trade see Estevadeordal, Frantz, and Taylor (2003), Flandreau and Maurel (2005), Jacks (2006), and López-Córdova and Meissner (2003). On the gold standard and bond spreads see Bordo and Rockoff (1996) and Obstfeld and Taylor (2003).

[4] However, as Hanes (1996) notes, controlling for the long run changes in the composition of the CPI, real wage cyclicality has been quite stable, and long-run comparisons need to allow for the greater countercyclicality of price markups on more finished goods.

[5] Though not central to this paper, there is also the related question as to whether the rigidities that supposedly characterized the interwar period persisted even longer—for the U.S. and U.K., at least, the evidence suggests not (Phillips, 1958; Hanes, 1996; Huang et al., 2004).

3. Theoretical perspectives

We develop a simple, static, small open-economy model that extends the analysis in Reinhart, Rogoff, and Spilimbergo (2003). This is a stylized, classical model that is designed to examine the impact of external shocks on small, open economies and the interaction between nominal rigidity and the exchange rate regime.

Our focus is on the response of the model to an external terms-of-trade shock, and the findings mesh with our subsequent empirical identification strategy. Why choose terms-of-trade shocks? Shocks to the major domestic macroeconomic observables are tainted by endogeneity. The levels of such variables could co-evolve with the real exchange rate and all other variables, and inference could be clouded by deep structural dynamics and underlying parameters. However, terms-of-trade shocks can be treated as exogenous, averting these identification problems, at least for small countries. Thus, in our empirical work we focus most closely on the case of small countries, since the exogeneity assumption is less open to question in these cases.

In our exercise, we also posit that trade is balanced period by period, hence we assume away financial adjustment channels via intertemporal trade or via portfolio diversification. These channels may of course be quite consequential in determining the international transmission of shocks, a point stressed by Corsetti, Dedola, and Leduc (2008), yet they do not make price rigidities redundant at the domestic level.

The key insight—common to many other more complex models of this sort—is that after a terms-of-trade shock, the presence of a nominal rigidity can lead the economy away from its first-best, flexible-price equilibrium; however, so long as they are unconstrained by a pegged exchange rate regime, policymakers can then employ a change in the nominal exchange rate to improve welfare and allow the economy to attain the first-best.

3.1. A model

The model economy has two sectors. The traded exportable good is a pure endowment good; it is not consumed at home, but is exchanged for an imported consumption good on world markets according to *exogenously* given terms of trade based on world prices denominated in foreign currency. A nontraded consumption good is produced at home using a single factor, homogeneous labor; the price of this good and the wage of labor (which are equal) are denominated in local currency, and they may be sticky. The consumer is a representative agent, who has preferences over imported goods, nontraded goods, and labor supply. The government sets the nominal exchange rate; for simplicity, money is not explicitly modeled.

We suppose the economy reaches equilibrium as follows. Home prices and wages are preset in nominal terms at the start of the period. A terms-of-trade shock is then observed, for example, a fall in the foreign-currency price of exports. Under perfectly flexible wages, this shock will cause internal wages and prices to adjust, and it will turn out that the level of the nominal exchange rate is immaterial: the exchange rate regime does not matter. Under sticky wages (of varying degrees) the level of the nominal exchange rate will matter. For example, the authorities might prefer to engineer a nominal devaluation to offset a decline in the terms of trade. The optimal degree of devaluation will depend on the characteristics of the utility function, the degree of nominal rigidity, and the size of the terms-of-trade shock.

We now make this argument formally. The economy is described by the following system of equations. The representative consumer has the utility function

$$U = \underbrace{[\alpha C^{\rho} + (1-\alpha)M^{\rho}]^{\frac{1}{\rho}}}_{U_1} + \underbrace{\left[-\frac{1}{\phi}L^{\phi}\right]}_{U_2}, \tag{1}$$

where C denotes the consumption of the nontraded good, M denotes the consumption of the imported good, and L denotes labor supply. For convenience, the two additive subutilities are denoted U_1 and U_2. Unlike Reinhart, Rogoff, and Spilimbergo (2003), who used a Cobb-Douglas aggregation in the utility component U_1, we employ a CES form for greater flexibility and sensitivity analysis.

The consumer's binding budget constraint is

$$p_C C + e p_M^* M = wL + e p_X^* X, \tag{2}$$

where p_c is the local-currency price of the consumption good, w is the local-currency wage, p_m^* is the exogenous foreign-currency price of the import good, p_x^* is the exogenous foreign-currency price of the export good, X is the amount of the export good with which the home country is exogenously endowed, and e is the nominal exchange rate which we assume is set by the government.

Competitive constant-returns-to-scale production of the non-traded good takes place using a labor input with a simple Ricardian technology

$$C = \gamma L, \tag{3}$$

where γ is an exogenous productivity parameter. The price of the nontraded good is then $p_c = w/\gamma$, which is true whether prices are sticky or flexible. These properties, plus the budget constraint, also imply that balanced external trade must hold, since $p_c C = wL$ implies $e p_M^* M = e p_x^* X$.

3.2. Solution

We now develop the model further so that we can study three cases: perfectly flexible wages, perfectly sticky wages, and partially sticky wages. Note that, since prices and wages are proportional under the competitive Ricardian technology, price stickiness and wage stickiness in the nontraded sector are one and the same thing here. From the standard Lagrangian, the relevant first order conditions can be solved for C and M and the multiplier λ, and hence utility.

Letting $z = w/e$ denote the local wage measured in foreign currency, the first component of utility can be written as:

$$U_1 = [\alpha C^{\rho} + (1-\alpha)M^{\rho}]^{\frac{1}{\rho}} = \left[\frac{p_X^* X}{p_M^*}\right]\left\{\alpha\left[\frac{1-\alpha}{\alpha}\right]^{\frac{\rho}{\rho-1}}\left[\frac{z}{p_M^*\gamma}\right]^{\frac{\rho}{\rho-1}} + (1-\alpha)\right\}^{\frac{1}{\rho}}. \tag{4}$$

Likewise, that the second component of utility can be written as:

$$U_2 = -\frac{L^{\phi}}{\phi} = -\frac{(\lambda w)^{\frac{\phi}{\phi-1}}}{\phi} = -\frac{1}{\phi}\left(\frac{z(1-\alpha)}{p_M^*}\right)^{\frac{\phi}{\phi-1}}\left\{\alpha\left[\frac{1-\alpha}{\alpha}\frac{z}{p_M^*\gamma}\right]^{\frac{\rho}{\rho-1}} + (1-\alpha)\right\}^{\left(\frac{1}{\rho}-1\right)\left(\frac{\phi}{\phi-1}\right)}. \tag{5}$$

Adding the two components together, utility $U = U(z;\ldots)$ is then a convex function of one endogenous variable, z, and a host of exogenous parameters and variables. The optimal level z that attains maximum consumer welfare will be denoted z^*, where $z^*(p_x^* X, p_M^*, \gamma, \alpha, \phi, \rho)$ depends on world prices, nontraded productivity, export endowments, and various parameters.

How does the economy get to z^*? If wages are flexible, regardless of whether the exchange rate is fixed, the economy ends up at the first best, as is well known. If wages are perfectly sticky, the economy is at a constrained optimum; yet fortunately, the government can still adjust the exchange rate to ensure that z attains its optimum value z^*, no matter where w is stuck. That is, a flexible exchange rate serves as a shock absorber in the classic fashion. Finally, in the intermediate case where wages are partially sticky, adjustment to any shock must be parceled out between changes in wages and changes in the exchange rate.

The essential intuition is hopefully clear: as in so many models of this type, the welfare-maximizing planning problem for the authorities is to ensure that the economy replicates the flexible price equilibrium. Ours is a particularly clean model of this type, with a simple structure of two sectors, one of which is an endowment sector. However, the intuition will certainly apply in more general models of the NOEM type.

3.3. Simulations

To explore the implications of the model for optimal exchange rate policy, we simulate the response to a 1% drop in the world price of the country's exports. The benchmark parameters are chosen as follows: $w=1; X=1; p_M^*=1; p_X^*=1; \alpha=0.5; \phi=1.25; \gamma=1; \rho=0$. The latter implies a Cobb-Douglas elasticity of substitution of $\sigma=1$ (where $\rho=1-\sigma^{-1}$). By way of sensitivity analysis, we also examined the cases $\sigma=0.5$ and $\sigma=1.5$. In an appendix, the choice of parameters is justified.

Since the optimal exchange rate policy is trivial (or immaterial) when wages are perfectly flexible, Fig. 1a examines the more interesting extreme case of perfect stickiness. For the benchmark Cobb-Douglas case ($\sigma=1$) a 1% fall in export prices calls for a 0.34% optimal nominal depreciation. What about the real exchange rate, denoted q? We compute this as the price of the local consumption basket relative to a hypothetical foreign basket. In these experiments, the price of the foreign country's import good is taken to be the same as the price of the home export good expressed in foreign currency. The price of the foreign nontraded goods is assumed fixed.

The optimal nominal depreciation, naturally, lowers the cost of home nontradables (measured in foreign currency), even though these are

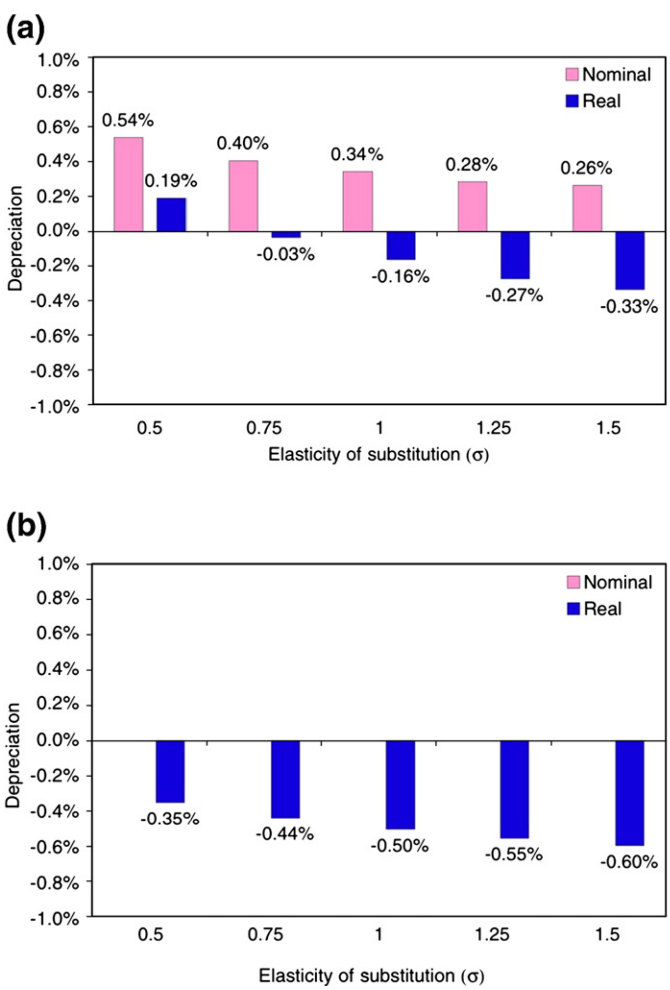

Fig. 1. (a) Model predictions with sticky wages and a flexible exchange rate. (b) Model predictions with sticky wages and a fixed exchange rate.

sticky in domestic currency terms. These goods constitute one half of a constant budget-weight consumption basket, causing the home price level to fall. Meanwhile, the foreign currency price of home exports is falling by assumption causing the traded part of the foreign price level to fall (measured in foreign currency). These two effects go in opposite directions. In the benchmark Cobb-Douglas case the resulting real depreciation is only −0.16%, that is, a real appreciation of 0.16%.

In the other cases, a large elasticity of substitution allows the authorities to get away with a much smaller nominal devaluation, since the necessary expenditure shifting can be achieved with a smaller price change. When $\sigma=1.5$, the optimal depreciation is only 0.26% in nominal terms with an opposing −0.33% real depreciation (a real appreciation where the terms-of-trade effect dominates). Conversely, when the elasticity is low, $\sigma=0.5$, the respective depreciations are 0.54% and 0.19% (a real depreciation where the nominal devaluation dominates). Within the range of values considered, we can define the value of the elasticity of substitution for which a terms-of-trade shock with optimal exchange rate policy causes neither real appreciation nor depreciation as $\sigma=\sigma_0$. Evidently, σ_0 is approximately equal to 0.75 with the model as calibrated here. Our historical evidence will later be seen to be consistent with such a value.

For intermediate degrees of wage stickiness, the implications are fairly obvious. Suppose stickiness were parameterized by s which takes a value between zero and one; flexibility would then be equal to $1-s$ and we could allow this to indicate what fraction of the adjustment towards the flex price equilibrium is attained. In that case, the optimal policy adjustment would take the form of a convex combination of a policy-driven exchange rate movement (equal to the above adjustments with a weight s), and a market-based wage and price movement (equal to the above adjustments with a weight $(1-s)$).

The bottom line of our model simulations under optimal floating is as follows. Unless the elasticity of substitution is low (well below 0.5) or high (well above 1.5) we expect to see the authorities respond to a 1% terms-of-trade shock with a nominal depreciation, with the result that the real exchange rate should change very little. If the elasticity of substitution is low (0.5) the nominal depreciation leaves a small real depreciation of 0.19%; if it is high (1.5) it leaves a small real appreciation of 0.33%. In the middle, for the Cobb–Douglas case, the real appreciation is 0.16%. If the elasticity of substitution is σ_0 (about 0.75) there is no real exchange rate response. For the range of parameters chosen, the goal of policy, in response to terms-of-trade shocks, is to smooth them out using exchange rate policy.

These optimal policy predictions contrast with the outcomes under suboptimal fixed exchange rates when stickiness is present. In Fig. 1b, which may be compared with Fig. 1a, we repeat the above exercises but we assume that the authorities are maintaining an exchange rate peg. Now, of course, in response to each shock to the home export price there is no nominal devaluation. Thus, the home price level is unchanged: the sticky wage keeps nontraded prices fixed, and import prices remain fixed because the world price and the exchange rate do not change. However, the foreign economy still sees its import price decline, causing its price level to rise by about 0.5%. As a result, the home country always experiences a real appreciation.

Crucially, for the empirical work that follows, the movements in the real exchange rate are much more volatile in the fixed case (Fig. 1b) than under optimal floating (Fig. 1a). It is this contrast that we will exploit to test for different responses under the two monetary regimes under sticky wages. If the elasticity of substitution is low (0.5) the real appreciation is 0.35%; if it is high (1.5) the real appreciation is 0.60%. In the middle, for the Cobb–Douglas case, the real appreciation is exactly 0.50%. That is, 1% fluctuations in the terms-of-trade cause real exchange rate fluctuations about 50% to 150% times larger under stickiness and fixed rates than under flexibility or optimal floating.

These general implications are summarized in Fig. 2 for a case where we assume that the elasticity of substitution is close to σ_0 (an assumption that we will be able to test). When wages and prices

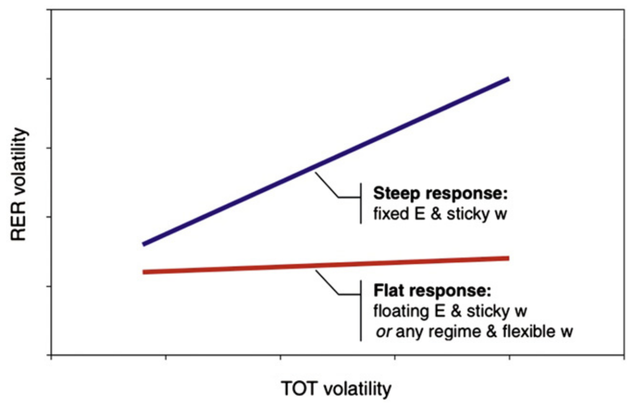

Fig. 2. Model predictions: RER volatility versus TOT volatility.

are flexible, the outcome will always be the same as under the optimal float, that is, a small response of real exchange rate volatility to terms-of-trade volatility (the flat line); this response may even be zero, depending on the elasticity parameter. In contrast, there should be a large response under a suboptimal peg when wages are sticky (the steep line).

Suppose we imagine an experiment in which, all else equal, terms-of-trade volatility increases and we observe the change in real exchange rate volatility. Our model then shows how stickiness and the exchange rate regime affect the parameter β in the equation

$$qvol = \beta \times TOTvol, \tag{6}$$

where *qvol* is a measure of real exchange rate volatility and *TOTvol* is a measure of terms-of-trade volatility, and all else is held constant. This is our empirical strategy to identify underlying structural changes in the economy.

For proper identification, we must clarify the sources of the shocks. Again, we emphasize that the terms of trade shock will be assumed to be exogenous. And we also assume that traded goods are priced in foreign currency. In what follows, estimation is based largely on data from small countries, where both of these assumptions make the most sense. Indeed, we will find that weaker results obtain when large countries are included. This is not surprising. In large countries, theoretical predictions are more complex, since trade is affected by monopolistic competition—that is, large countries are not "price takers" in world markets. Local currency pricing of traded goods will also affect the predictions of this type of model. In more general cases, the relationship between changes in the terms of trade and changes in the real exchange rate are then likely to be conflated by the general equilibrium effects of traded and nontraded sectors, price setting, home bias, trade elasticity, risk sharing, and a host of other factors (Devereux and Engel 2002, 2007; Corsetti, Dedola, and Leduc, forthcoming).

Referring to Eq. (6), we now arrive at the hypothesis that will be central to the rest of this paper: in a perfectly flexible economy, there will be no difference between the β measured under fixed and (optimal) floating rate regimes. But if stickiness is present, this should be detectable in a measurable change in β under fixed versus floating rates.

To sum up the lessons as we move from theory to empirics: (1) the extent of pass through from terms-of-trade shocks to the real exchange rate is an empirical matter (absent knowledge of deep parameters); but (2) its extent depends on the exchange rate regime only when nominal rigidities are present.

4. From theory to empirics: evaluating the classical and interwar gold standards

The general lessons of this type of model for our historical study are as follows. If prices are flexible, which we use as a simplifying assumption for the pre-1914 period, then a fixed regime has few costs. But once prices become stickier, as was supposedly the case in the interwar period, a different calculus emerges. Then, under a floating rate regime, monetary policy can be activated to offset an adverse terms-of-trade shock, allowing for some adjustment via nominal depreciation. The volatility of the real exchange rate will be muted. Under a fixed regime, however, with nominal rigidities, the same shock will spill over much more into the real exchange rate. This suggests we follow an empirical strategy that relates real exchange rate volatility to the monetary regime and the size of the external shocks, and where we also search for differential impacts of the gold standard on real exchange rate volatility in different eras.

To help guide this strategy we turn to the extant literature on the determinants of real exchange rate volatility. Rose and Engel (2002) develop a comprehensive framework for examining the determinants of real exchange rate volatility. They use panel regressions to relate the volatility of the real exchange rate to independent variables familiar from the gravity model: "mass" (income and per capita income), monetary measures (nominal exchange rate volatility and a currency union dummy), and various geopolitical measures (landlocked, common border, free trade agreement, colonial relationship). Their estimating equations are of the form:

$$qvol_{ijt} = \beta_{0i} + \beta_{0j} + \beta_1 evol_{ijt} + \beta_2 ERregime_{ijt} + \gamma Z_{ijt} + \varepsilon_{ijt}, \tag{7}$$

where, $qvol_{ijt}$ is the real exchange rate volatility for county-pair $i-j$; $evol_{ijt}$ is the nominal exchange rate volatility for country-pair $i-j$; $ERregime_{ijt}$ is an indicator variable (or a vector of indicators) for the exchange rate regime; and Z_{ijt} is a vector of "gravity" variables.

The literature has also recognized that real exchange rate volatility may, in general, depend on the size of the nontraded sector in the economy. Thus, Hau (2002) uses theory to explain why one should also include a measure of the trade share (or "trade openness") of the economy as an important additional control variable (akin to the trade weight α in our model). His estimating equation is:

$$qvol_{ijt} = \beta_{0i} + \beta_{0j} + \beta_1 evol_{ijt} + \beta_2 ERregime_{ijt} + \beta_3 (Trade/GDP)_{ijt} + \gamma Z_{ijt} + \varepsilon_{ijt}, \tag{8}$$

where $Trade/GDP_{ijt}$ is the average trade share for country pair $i-j$.

Our model provides two reasons to augment the prevailing approach to estimating equations such as (7) and (8). A first refinement to these empirical designs is suggested by Eq. (6). Our model suggests that the larger the terms-of-trade shock, the larger is the necessary adjustment, although this slope should depend on the exchange rate regime and the degree of wage flexibility (Fig. 2). This will turn out to be very important empirically below, where we estimate variants of a benchmark econometric model of the form

$$qvol_{ijt} = \beta_{0i} + \beta_{0j} + \beta_1 evol_{ijt} + \beta_2 GS_{ijt} + \beta_3 (Trade/GDP)_{ijt} + \beta_4 TOTvol_{ijt} + \varepsilon_{ijt}, \tag{9}$$

where observations are a non-overlapping 5-year window of annual data for each country pair; GS_{ijt} is an indicator variable for gold standard adherence for country-pair $i-j$; $TOTvol_{ijt}$ is the terms-of-trade volatility for country-pair $i-j$; and β_{0i} and β_{0j} are country fixed effects.

Crucially, we will allow the slope parameter β_4 to vary according to the exchange rate regime (GS), in order to match the qualitative predictions of our model in Fig. 2. Hence we set

$$\beta_4 = \beta_{40} + \beta_{41} GS_{ijt}, \tag{10}$$

where β_{40} is the slope when the country is floating and β_{41} is the change in slope when the country is on the gold standard. If our model is correct, we expect $\beta_{41}=0$ if the economy is flexible (no difference between the fixed and floating cases) and $\beta_{41}>0$ if the economy has nominal rigidities (more volatility under a fixed exchange rate than under optimal floating).

To sum up, our model suggests that the impact of a gold standard regime will be to raise the slope parameter β_4 under conditions of nominal rigidity. Controlling for all other effects, we can think of shifts in β_4 from one era to the next as evidence of structural changes.

5. Data

Our panel dataset comprises quinquennial country-pair observations for a large set of small countries over the period from 1875 to 1939 (e.g., 1875–79, 1880–84, etc.). We omit data corresponding to World War One and the German hyperinflation of 1922/23 for obvious reasons.

The data on consumer price indices and annual nominal exchange rates are from the Global Financial Database, with some corrections by the authors. The set of countries comprising the sample can be found in Table 1. However, as explained earlier, to permit confidence in our identification strategy, we explicitly focus on the case of small countries with little or no monopoly power on the terms of trade. In this light, observations including the four major manufacturing exporters—the United States, Britain, France and Germany—plus Brazil, the one large commodity exporter in our sample often considered to have market power (at least for one product, coffee) are reserved for a robustness exercise reported in Table 5 below. This focus delivers not only desirable exogeneity properties for the estimation, but also hems most closely to the model presented above.

To construct real and nominal exchange rate volatilities we follow standard practice: we take the first difference of the log bilateral exchange rate and then calculate their standard deviations over the five-year windows. As we can see from Table 2, the volatility of real exchange rates changed markedly after World War One. Average real exchange rate volatility rose from 0.080 to 0.173. Its standard deviation also increased from 0.049 to 0.109. Locating the underlying causes of these changes is a major goal of this paper.

We use a gold standard indicator variable (labeled GS3) set equal to one for quinquennial periods when both countries *i* and *j* were on the gold standard for at least 3 out of the 5 years. Under this definition, approximately 32.1% of the country-pair observations in our dataset were on the gold standard before World War One. This proportion decreased to 8.5% for the post-1918 sample, as expected—the interwar gold standard was fragile and short-lived. As a robustness check we also construct an alternative gold standard indicator GS5, set equal to one for periods when both countries *i* and *j* were on the gold standard for *all* 5 years in the quinquennial window. This produces materially similar results, but suffers from a lack of precision given the low observation count of countries which were "small" and which fastidiously adhered to the gold standard in the interwar period.

We define the terms of trade (TOT) for each country in the sample as the relative price of exports in terms of imports, using data from Hadass and Williamson (2003). Bilateral TOT volatility is then computed as the standard deviation of the ratio of the terms of trade for countries *i* and *j* over five-year windows. That is, we consider each country to be importing the "world" basket of goods with price P^W, but exporting its own unique basket of goods with price P_i^X. Thus, the terms of trade against the world for country *i* is P_i^X/P^w but for country *i* against country *j* bilaterally the terms of trade are $P_i^X/P_j^X = (P_i^X/P^w)/(P_j^X/P^w)$. For the countries in our dataset Table 2 shows that TOT volatility increased from 0.086 in the pre-1914 sample to 0.128 in the post-1918 sample. The standard deviation similarly increased from 0.046 to 0.080. This is also unsurprising: it is well known that the amplitude of terms-of-trade shocks grew enormously in the interwar period as compared to the prewar period (Kindleberger 1973).

We also construct a measure of openness for each country as the ratio of trade with all trading partners (exports plus imports) to GDP. For our regression analysis we then use a measure of openness for each country pair which was computed as the average of openness variables for countries *i* and *j* over five-year windows. These data were sourced from Global Financial Data and are based on the compilations of Mitchell (1992a,b, 1993a,b).

Table 1
Countries in the sample

Argentina	France[c]	Portugal
Australia	Germany[c,a]	Rhodesia
Austria[b]	Greece	Russia[b]
Brazil[c]	India	Spain
Canada	Italy	Sweden
Chile	Japan	Turkey[b]
China	Mexico	The United Kingdom[c]
Colombia	New Zealand	The United States[c]
Denmark	Norway	Uruguay
Egypt	Peru	

Notes:
[a] Excludes hyperinflationary years of 1922/3.
[b] In our data we code Austria = Austria–Hungary, and Turkey = Ottoman Empire before the breakup of these empires; and we code Soviet Union = Russia after the Revolution.
[c] Large country excluded from most empirical results.

Table 2
Summary statistics

	Observations	Mean	Standard deviation
(a) Prewar period			
Real exchange rate volatility	346	0.080	0.049
Nominal exchange rate volatility	346	0.066	0.057
Gold standard indicator GS3*	346	0.321	0.467
Average openness	346	0.237	0.107
Distance (logged)	346	8.061	1.073
TOT volatility	346	0.086	0.046
Gold standard GS3×TOT volatility	346	0.027	0.047
(b) Interwar period			
Real exchange rate volatility	483	0.173	0.109
Nominal exchange rate volatility	483	0.170	0.123
Gold standard indicator GS3*	483	0.085	0.279
Average openness	483	0.178	0.084
Distance (logged)	483	8.451	0.810
TOT volatility	483	0.128	0.080
Gold standard GS3×TOT volatility	483	0.008	0.032

Notes: * Gold standard indicator is GS3 (pair on gold standard at least 3 years out of 5). The unit of observation is the country-pair quinquennium.

6. Results

The dependent variable in all of our regression specifications is the volatility of the real exchange rate. Throughout, we estimate a series of regressions pooling observations from before 1914 (denoted "prewar") and from after 1918 (denoted "interwar"). We pool all prewar and interwar observations and estimate a single fixed effects specification with a full set of interactions between the benchmark model regressors and the two period dummies in order to clearly demonstrate that the difference in point estimates across regimes is, indeed, statistically significant. The test of our central hypothesis is then very cleanly reduced to determining the significance of the interaction term involving the gold standard, TOT volatility, and the interwar period dummy.

Following the augmented Rose and Engel (2002) country-fixed effects (CFE) specification of Eq. (9), the results of our initial specification are reported in the first two columns of Table 3. Including the country fixed effects, the *R*-squared shows that this specification captures 85% of the variation for the two periods. As expected, for both the pre-1914 and post-1918 periods nominal exchange rate volatility explains much of the variation in real exchange rate volatility: the coefficients on the nominal exchange rate are positive and highly significant. The estimated coefficient for

Table 3
Estimates — country fixed effects (CFE) and country-pair fixed effects (CPFE)

	(1) Prewar, CFE	(2) Interwar, CFE	(3) Prewar, CPFE	(4) Interwar, CPFE
Nominal ER volatility	0.311	0.866	0.297	0.879
	(5.22)**	(35.44)**	(4.57)**	(34.39)**
Openness	0.007	0.093	0.018	0.116
	(0.16)	(2.66)**	(0.34)	(3.04)**
GS3	0.005	-0.030	0.011	-0.041
	(0.38)	(3.01)**	(0.62)	(3.30)**
TOT volatility	−0.002	−0.003	0.036	−0.015
	(0.03)	(0.10)	(0.49)	(0.44)
GS3×TOT volatility	−0.109	0.335	−0.144	0.435
	(1.08)	(3.73)**	(1.10)	(3.55)**
Observations	829		829	
R-squared	0.85		0.87	

Notes: Robust *t*-statistics in parentheses. *significant at 5%; **significant at 1%. Dependent variable is real exchange rate volatility in a 5-year window, Prewar 1875–1914 and Interwar 1920–39.

the pre-1914 period is 0.311, and rises to 0.866 in the post-1918 period. In this regression we find no separate impact of the gold standard on real exchange rate volatility in the pre-1914 period—that is, independent of its impact on reduced nominal exchange rate volatility, which was substantial—and a negative, but quantitatively small effect for the post-1918 period.

TOT volatility should also be a determinant of real exchange rate volatility. In order to test this hypothesis we include our measure of TOT volatility and an interaction term between the gold standard indicator (GS3) and TOT volatility as independent variables. Using the GS3 indicator, the coefficient on TOT volatility is negative and insignificant for both the pre-1914 and post-1918 periods. The coefficient on the *interaction* term for the gold standard and TOT volatility is insignificant for the pre-1914 sample (−0.109); but it is positive and highly statistically significant for the post-1918 sample (0.335). Higher TOT volatility was associated with higher RER volatility—but only in the interwar years, and only for countries on gold.

As a check on the robustness of our results, we re-estimate the specification in columns 1 and 2 of Table 3 but this time using country-pair fixed effects (CPFE) estimation. The logic behind CFE estimation is that bilateral real exchange rate volatility may be affected systematically by (time-invariant) country-level attributes not captured in the right-hand side variables, but which can be captured in a full set of country dummies. However, the omitted variable problem may be more serious if there are also unobservable (time-invariant) pair-specific characteristics that affect real exchange rate volatility. In that case, the safest way to proceed is by including a full range of country-pair dummies.

These results are shown in columns 3 and 4 of Table 3. They are quite similar to the results with country fixed effects (CFE). The coefficients on GS3 and TOT volatility are somewhat larger than previously, but are statistically indistinguishable while the coefficient on the GS3−TOT volatility interaction term increases 30% in size for the post-1918 period (0.335 in column 2 versus 0.435 in column 4).

To sum up, according to our preferred results (Table 3, columns 3 and 4), TOT volatility has no statistically significant effect on RER volatility before 1914. But after 1919, an increase in TOT volatility increased RER volatility (with a passthrough coefficient of 0.435), *but only for countries on the gold standard*. These differences between the two epochs are highlighted graphically in Fig. 3, which shows predicted values for RER volatility as a function of TOT volatility (and with other variables fixed at their sample means) based on our preferred results. Panel (a) displays the prewar predictions, and panel (b) the interwar predictions, and in each case we show the fitted values for on gold versus off gold, along with ±1 standard error bounds. Since the interpretation of interaction effects based on tabulated coefficients can be problematic, this figure presents the clearest indication that fixed and floating regimes were similar in the prewar period, but different in the interwar period. The relevant slope for the interwar-fixed countries is clearly much higher than for the interwar-floating countries.

7. Robustness checks and discussion of results

7.1. Core versus periphery

We next consider the possibility that heterogeneity across core and periphery countries may be driving the results of Table 3. To this end, Table 4 repeats the pooled country-pair fixed effect specification for purely core country pairs (columns 1 and 2), mixed core–periphery country pairs (columns 3 and 4), and purely periphery country pairs (columns 5 and 6). The core countries are Australia, Austria, Belgium, Canada, Denmark, Luxembourg, Netherlands, New Zealand, Norway, Sweden, and Switzerland. The remaining countries are considered to be in the periphery. The results in Table 4 suggest that the emergence of an interwar interaction effect between TOT volatility and the gold standard was most pronounced in the core countries: the magnitude and significance of the effect diminishes as one moves from left to right. This is in line with the expectation that nominal rigidities became more prevalent in the developed countries, given their larger manufacturing sectors, and the increase in democratization and labor militancy after World War One.

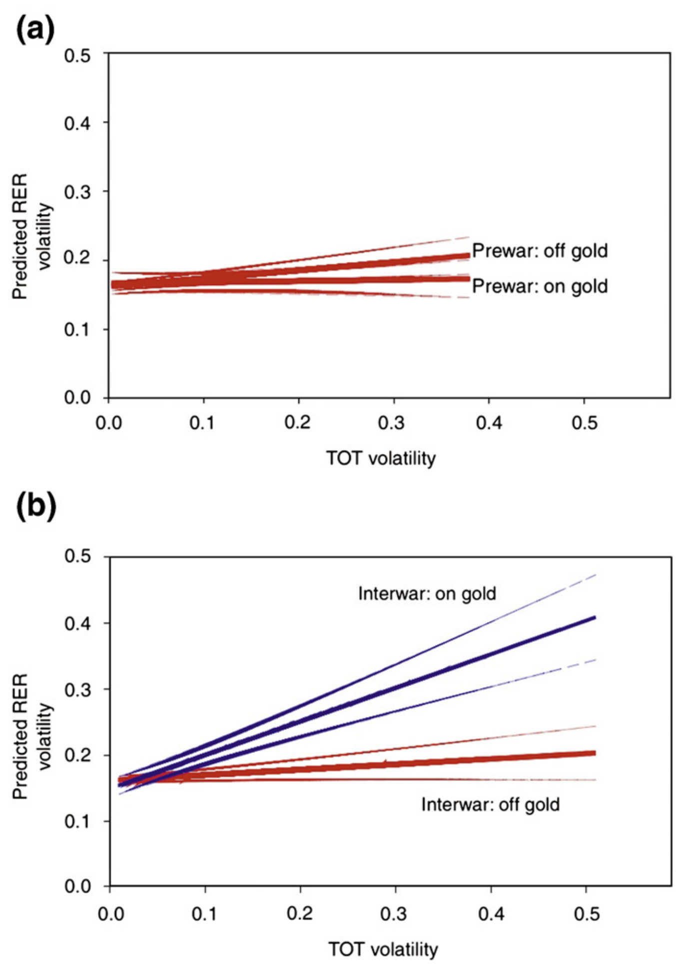

Fig. 3. (a) Prewar data: predicted RER volatility versus TOT volatility. (b) Interwar data: predicted RER volatility versus TOT volatility.

Table 4
Estimates — allowing for core and periphery (CPFE)

	(1) Prewar, core	(2) Interwar, core	(3) Prewar, mixed	(4) Interwar, mixed	(5) Prewar, periphery	(6) Interwar, periphery
Nominal ER	0.781	0.952	0.394	0.875	0.203	0.892
volatility	(2.28)*	(16.69)**	(3.98)**	(28.44)**	(2.30)*	(19.66)**
Openness	−0.302	−0.011	−0.026	0.113	0.092	0.279
	(2.11)*	(0.23)	(0.80)	(2.48)*	(0.90)	(1.68)*
GS3	−0.018	−0.052	0.023	−0.031	0.013	−0.009
	(0.99)	(2.56)*	(1.16)	(1.63)	(0.29)	(0.18)
TOT volatility	−0.336	0.159	0.033	0.026	0.068	−0.066
	(0.67)	(2.26)*	(0.40)	(0.70)	(0.55)	(0.81)
GS3×TOT	0.297	0.807	−0.230	0.379	−0.162	0.178
volatility	(0.59)	(2.09)*	(1.48)	(2.01)*	(0.54)	(0.70)
Observations	74		463		292	
R-squared	0.97		0.88		0.85	

Notes: Robust *t*-statistics in parentheses. *significant at 5%; **significant at 1%. Core refers to core/core pairs, mixed refers to core/periphery pairs, and periphery refers to periphery/periphery pairs. The (small) core countries are Australia, Austria, Belgium, Canada, Denmark, France, Germany, Luxembourg, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, and United States. The rest are periphery.
Dependent variable is real exchange rate volatility in a 5-year window, Prewar 1875–1914 and Interwar 1920–39.

7.2. Country size and terms-of-trade exogeneity

One of our key identifying assumptions has been the exogeneity of the terms-of-trade in the small country case. As a robustness check we ask whether our results would be affected by pooling across both large and small countries in the dataset. To the extent that we rely on an assumption of TOT exogeneity, we expect our results to rest on a stronger foundation when we exclude large countries where the "small open economy" assumption may be in doubt. Table 5 reports results when we restrict the sample to small-small pairs, mixed large-small pairs, and large-large pairs and reestimate. As before, the large countries consist of the four major manufacturing exporters—the United States, Britain, France and Germany—plus Brazil. The results are precisely as expected. In all cases, there is no interaction effect in any prewar sample (columns 1, 3, and 5). However, in the interwar period, the large country sample shows no statistically significant interaction effect (column 6) while the mixed and small country samples show an effect that is both positive and statistically significant (columns 2 and 4). Thus, the use of small-small country pairs as our benchmark seems justified, given the questionable exogeneity of the terms-of-trade in the case of large-large country-pairs.

Table 5
Estimates — allowing for large countries (CPFE)

	(1) Prewar, small	(2) Interwar, small	(3) Prewar, mixed	(4) Interwar, mixed	(5) Prewar, large	(6) Interwar, large
Nominal ER	0.297	0.879	0.549	0.854	0.380	0.954
volatility	(4.57)**	(34.39)**	(7.05)**	(26.19)**	(2.65)**	(5.45)**
Openness	0.018	0.116	0.051	0.013	0.332	0.057
	(0.34)	(3.04)**	(1.64)	(0.21)	(2.81)**	(0.23)
GS3	0.011	−0.041	0.017	−0.018	−0.009	0.025
	(0.62)	(3.30)**	(1.28)	(1.26)	(0.62)	(0.40)
TOT volatility	0.036	−0.015	−0.001	−0.012	−0.039	−0.110
	(0.49)	(0.44)	(0.20)	(0.26)	(0.39)	(0.51)
GS3×TOT	−0.144	0.435	−0.141	0.449	−0.026	0.174
volatility	(1.10)	(3.55)**	(1.51)	(2.88)**	(0.24)	(0.22)
Observations	829		633		99	
R-squared	0.87		0.85		0.91	

Notes: Robust *t*-statistics in parentheses. *significant at 5%; **significant at 1%. Columns 1 and 2 are same as Table 3, columns 3 and 4. Large refers to large/large pairs, mixed refers to large/small pairs, small refers to small/small pairs. The large countries are USA, UK, France, Germany, and Brazil. The rest are small.
Dependent variable is real exchange rate volatility in a 5-year window, Prewar 1875–1914 and Interwar 1920–39.

Table 6
Estimates — allowing for high sterilizers (CPFE)

	(1) Prewar, pooled	(2) Interwar, pooled	(3) Prewar, high	(4) Interwar, high	(5) Prewar, other	(6) Interwar, other
Nominal ER	0.297	0.879	0.271	0.976	0.356	0.824
volatility	(4.57)**	(34.39)**	(3.16)**	(18.92)**	(3.19)**	(27.08)**
Openness	0.018	0.116	0.050	0.282	-0.023	0.022
	(0.34)	(3.04)**	(0.78)	(3.54)**	(0.34)	(0.52)
GS3	0.011	-0.041	0.004	−0.046	0.031	−0.045
	(0.62)	(3.30)**	(0.20)	(2.14)*	(1.08)	(3.08)**
TOT volatility	0.036	−0.015	−0.004	−0.093	0.281	0.056
	(0.49)	(0.44)	(0.04)	(1.40)	(2.08)*	(1.42)
GS3×TOT	−0.144	0.435	−0.085	0.390	−0.388	0.614
volatility	(1.10)	(3.55)**	(0.50)	(2.74)**	(1.49)	(3.71)**
Observations	829		312		517	
R-squared	0.87		0.86		0.89	

Notes: Robust *t*-statistics in parentheses. *significant at 5%; **significant at 1%. Columns 1 and 2 are the same as Table 3, columns 3 and 4. Columns 3 through 6 split the sample into high and low sterilizers based on our constructed sterilization index as described in the text.
Dependent variable is real exchange rate volatility in a 5-year window, Prewar 1875–1914 and Interwar 1920–39.

7.3. Adjustment, sterilization, and the gold standard "rules of the game"

Our next robustness check considers a different objection: the problem that some countries on the interwar gold standard often deviated significantly from the traditional "rules of the game" by using sterilized interventions to block the adjustment of gold stocks, money supplies, and hence the workings of Hume's price-specie-flow mechanism.[6] This type of policy response could certainly interfere with the argument we have presented here, and cloud our empirical results, since countries with a high propensity to sterilize gold flows might inhibit the smooth adjustment of relative prices. For example, a gold inflow (and trade surplus) country, such as France in the 1930s, might not be keen to monetize its gold inflows. Why? Inflation of its export prices would go hand in hand with general price inflation, which was not welcome given other policy goals, even though it would have restored general open-economy macroeconomic equilibrium. For such countries, the use of sterilization might have fundamentally affected real exchange rate dynamics and volatility. The concern might then arise that interwar sterilization policies, rather than nominal rigidities per se, might have been the cause of the peculiar results in the interwar sample.

To address this concern, we divide our sample based on sterilization activity and reestimate. To make this partition we use Nurkse's (1944, p. 69) "rules of the game" sterilization indicator. Nurkse's indicator showed for a large sample of countries whether the central bank's foreign and domestic assets moved in the same direction in any given year, as would be dictated by gold standard orthodoxy. Based on this annual indicator, and using data on gold standard adherence from Estevadeordal, Frantz, and Taylor (2003), we

[6] According to Hume's logic, a country suffering a gold drain would experience a monetary contraction, and hence (eventually) a fall in its price level, ceteris paribus. Similar but opposite adjustment via money expansion, inflation and real appreciation would befall gold-inflow countries, and sustained adjustment in this fashion would continue until a balance-of-payments equilibrium was reached. Clearly, for this symmetric story to work smoothly and rapidly, two key assumptions must hold. First, we must assume that prices are not sticky, the main point at issue in this paper. Second, we also have to assume a willingness of the authorities to adhere to the rules of the game, and not "sterilize" the gold flows (leaving money supplies unchanged). For the most part, economic historians have concluded that these rules were more or less observed until World War One, but much less so thereafter. This holds despite well-known short-run deviations from this practice at times, especially by the major centers such as London and Paris. Using "gold devices" and other policies, central banks could partially and temporarily avoid the full force of the adjustment mechanism. See Bloomfield (1959), Eichengreen (1992), Sayers (1957), and Scammell (1965).

compute the number of years N in which each country was on gold *and* engaging in sterilization. We then compute the sum of N for both countries in the pair, taking the "high sterilizer" pairs to be those for which this sum exceeds its median value of 9.

The results are shown in Table 6. Columns 1 and 2 reproduce the results in Table 3, columns 3 and 4 as a benchmark. In columns 3 through 6 we then split the sample into high and low sterilizers. As we know, the interaction coefficient is strong for the whole sample in the post-1918 period (column 2). But the same holds true for high-sterilizer pairs (column 4) and low-sterilizer pairs (column 6). Although the difference between these two interaction coefficients is not statistically significant, the one for the high-sterilizer pairs is smaller and not as significant. Thus, deviation from the rules of the game via sterilization may have allowed some countries to partially avoid the problems caused by the rising magnitudes and impacts of terms of trade shocks in the interwar period. However, this room for maneuver was apparently insufficient to fully avoid the adverse impact of terms of trade shocks, and our basic argument holds for high and low sterilizer samples.

7.4. Unobserved time-varying effects

A final concern is that systematic changes in the world economy after World War I may be driving these results. In a large range of theoretical models, changes in various structural characteristics such as productivity shocks, nontraded goods, price setting, home bias, trade elasticities, risk sharing, and a host of other factors vitally affect the interaction between real exchange rates and the terms of trade (Devereux and Engel 2002, 2007; Corsetti, Dedola, and Leduc, forthcoming).

Even in our simple model, these problems are not absent. For instance, productivity shocks buffeting the economies of the time may have been marked by a heightened frequency or amplitude after World War I. But for this historic epoch we have no reliable direct measures of the needed control variables, such as country-level annual productivity (e.g., from Solow residuals). In essence, changes in unobserved time-varying effects may be problematic for inference when using pooled data from each period.

However, we can relax a restriction on the fixed effects to deal with any general kind of era-specific heterogeneity of this form. Up to this point, we have relied on country-pair fixed effects to control for unobservable (time-invariant) pair-specific characteristics that affect real exchange rate volatility. As an ultimate robustness check, we introduce both country-pair-invariant year effects and country-pair-variant era (prewar/postwar) effects. The basic idea is that annual changes in volatility in the global economy will be controlled for in the former case and that country-pair level (and by extension, country level) changes in volatility occasioned by World War I will be controlled for in the latter case.

To this end, in Table 7, we report specifications with year and country-pair fixed effects (columns 1 and 2) time-varying country-pair fixed effects (columns 3 and 4), and both types of effects (columns 5 and 6) in regressions pooling across the prewar and interwar periods. Yet again, our main finding is robust. We still find the same asymmetry between the prewar and interwar periods that we first detected in Table 3: higher TOT volatility was associated with higher RER volatility—but only in the interwar years, and only for countries on gold.

Table 7
Estimates — allowing for time-varying effects (CPFE)

	(1) Prewar, all obs.	(2) Interwar, all obs.	(3) Prewar, all obs.	(4) Interwar, all obs.	(5) Prewar, all obs.	(6) Interwar, all obs.
Nominal ER volatility	0.214 (3.37)**	0.859 (35.48)**	0.291 (4.33)**	0.873 (31.44)**	0.206 (3.11)**	0.851 (33.72)**
Openness	−0.075 (1.31)	−0.097 (1.63)	0.050 (0.73)	0.118 (2.90)**	−0.041 (0.54)	−0.174 (2.46)*
GS3	0.002 (0.16)	−0.015 (1.25)	0.015 (0.71)	−0.035 (2.58)**	0.005 (0.31)	−0.013 (0.99)
TOT volatility	0.131 (1.99)*	−0.044 (1.35)	0.049 (0.61)	0.022 (0.50)	0.118 (1.63)	−0.037 (0.87)
GS3×TOT volatility	−0.084 (0.80)	0.449 (3.84)**	−0.179 (1.19)	0.373 (2.72)**	−0.101 (0.88)	0.428 (3.43)**
Period fixed effects?		YES		NO		YES
Era-specific CPFEs?		NO		YES		YES
Observations	829		829		829	
R-squared	0.90		0.88		0.91	

Dependent variable is real exchange rate volatility in a 5-year window.
Note: Robust t-statistics in parentheses. *significant at 5%; **significant at 1%. Columns (1) and (2) report coefficients for the full prewar/interwar pooled sample interacted with prewar and interwar dummies as well as period fixed effects for each quinquennium. Columns (3) and (4) repeat the same exercise but with CPFEs interacted with prewar and interwar indicators. Columns (5) and (6) repeat the same exercise but with both period fixed effects and CPFEs interacted with prewar and interwar indicators. Dependent variable is real exchange rate volatility in a 5-year window, Prewar 1875–1914 and Interwar 1920–39.

7.5. Summary: comparing the results with the model

What do these results tell us? First, absent any reliable estimates of the elasticity of substitution from the literature, we can use the empirical results to approximately identify this parameter. Recall from Fig. 1 that if the elasticity of substitution is close to σ_0 (about 0.75) then there is no real exchange rate response in our model under flexible wages, or under sticky wages with optimal exchange rate policy: it is optimal to smooth the real exchange rate. The flat response of the real exchange rate to terms-of-trade shocks under both prewar and interwar floating regimes provides prima facie evidence in favor of a model with an elasticity of substitution close to σ_0. This might justify our earlier assumption that this was the case, as when we were laying out the qualitative predictions displayed in Fig. 2.

Our essential bottom line is that the correspondence between the empirical results in Fig. 3 and the theoretical predictions in Fig. 2 is striking. As shown by the flat lines, floats in both eras absorbed shocks well, as the model would have predicted. But for pegging, the pre-1914 gold standard absorbed shocks quite well; but after the war we see that increases in terms-of-trade volatility were associated with increases in real exchange rate volatility. In our model, as shown in Fig. 2, this latter kind of response is only seen in one case: *fixed regimes with stickiness*. This is the central result of our paper and is consistent with the oft-repeated—but hitherto unsubstantiated—view that the prewar global economy was sufficiently flexible to cope well with a fixed exchange rate regime, but the interwar gold standard was not.

Our paper therefore documents the rising importance of exchange rate flexibility as a shock absorber in the early twentieth century, a new finding that underscores the tensions highlighted by the trilemma-inspired account of the political economy of international finance (Obstfeld, Shambaugh, and Taylor 2005). Before 1914 the classical gold standard operated by the rules in an environment in which nominal flexibility, albeit not perfectly fluid, was sufficient to allow the classical adjustment mechanism to work through price levels alone. In contrast, by the 1920s and 1930s adopting a peg proved costly in terms of enhanced real exchange rate volatility. With flexibility apparently lost elsewhere in the macroeconomic system, the role of the exchange rate as a shock absorber suddenly became very important. This is, we believe, the first systematic, cross-country, and cross-regime study to document this crucial development.

8. Conclusion: from unfettered wages to golden fetters?

One of the unifying themes in global macroeconomic history concerns the shift in the adjustment process in the early twentieth century. It is widely believed that nominal rigidities increased, setting the stage for the Great Depression and the Keynesian revolution. But what is missing in the literature is systematic cross-country and cross-regime evidence, using consistent methods to evaluate the magnitude of these supposed changes. To help fill the gap we use theory to develop a new diagnostic test that can be applied to panel data from a large sample of countries.

Changes in nominal rigidities can have implications for optimal monetary policy, as can be seen in a simple classical model, or even in more complex models. In the presence of external terms-of-trade shocks, these rigidities drive a small open economy away from its first-best. For plausible parameters these same rigidities also raise the volatility of the real exchange rate, providing us with an indirect test for the changing strength of such rigidities. The implied diagnostic test: did the ability of the gold standard to absorb terms-of-trade volatility worsen significantly between the prewar period and the interwar period as measured by real exchange rate volatility? Our comparative evidence, summarized in Fig. 3, suggests that it did.

Two caveats must be offered. First, our model is an important guide, but is a simplification. That said, we believe the intuition will survive in many other models too. The basic point is robust. If an economy is fully flexible, there is no link between real and monetary outcomes, and the exchange rate regime should make no difference at all. Thus, even absent any specific model, the key results in Fig. 3 present a puzzle to be explained with respect to one important real linkage—the pass through of terms-of-trade shocks into real exchange rate shocks. The exchange rate regime seemed to make no difference before the war, but it did make a difference after the war. Why? Which parameters changed? Whatever models other scholars bring to the study of these data, this is a puzzle that must be confronted.

Second, given the limitations of a simple model and panel econometrics, our findings should not be interpreted as a monocausal explanation of the failure of the interwar gold standard. The economic—and political—story is much more complex than that (Eichengreen 1992). Country experiences varied greatly, and this will not be captured in our panel coefficient estimates. Still, as argued by Temin (1989), a rigorous account requires attention to both *impulse* and *propagation* effects; he drew special attention to the major impulse given by the shock of World War One and its aftermath, which disturbed exchange parities and the global allocation of gold reserves. Our work draws attention to a potentially important change in the propagation mechanism. Before 1914, it seems the world economy had enough flexibility that it could ride out terms-of-trade shocks even on a hard peg, so that the benefits of shifting to a floating rate regime were rather small. By the 1920s, this kind of flexibility was in decline just as terms-of-trade volatility was on the rise—an unfortunate combination that surely played some part in a crisis that brought to an end the world's most durable fixed exchange rate regime.

Appendix Parameter values

In the model of section 3, world prices, wages, export endowments, and the nontraded productivity parameter can be chosen without loss of generality. What about the trade share? Many authors have drawn attention to the high share of traded output circa 1900 compared with more recent periods (e.g. Irwin 1996). Thus, although some authors propose higher weights on nontraded goods for contemporary analysis (sometimes as high as 75%), a weight of 50% on traded goods seems about right in the gold standard era when tertiary sector activity was much smaller. For example, a figure of 50% accords with the rough share of "traded" sectors in U.S. GDP circa 1900, where "traded" is taken to mean agriculture, mining, and manufacturing in the Census Bureau's (1975) *Historical Statistics*. In less advanced economies, the share of nontraded services may have been even smaller than in the United States.

This leaves two key parameters to be chosen, the parameter ϕ, which is related to the labor supply elasticity, and the parameter ρ, which is related to the elasticity of substitution. Simulation results and inference will be sensitive to these parameters, so careful choices need to be made. We follow the real business cycle literature and set $\phi = 1.25$, which implies a "high" labor supply elasticity of 4 (see, e.g. Burstein et al., 2005). In that literature, at least, there seems to be some consensus on this value.

There is much less consensus on the appropriate parameter value for the elasticity of substitution in a model of this kind, hence the need for sensitivity analysis. Because this is the trickiest of the parameter choices, we discuss our choices at some length.

It has proven quite difficult for empirical researchers to pin down with accuracy the elasticity of substitution, especially at high levels of aggregation. Anderson (1998) states that "elasticities of substitution are assumed with little empirical foundation. In order to restrict the response of the nontraded good price in the model, the elasticity of transformation in the base case is quite high, equal to 5." Still, there now exist some estimates this high, such as those of Hummels (1999) as cited by Anderson and van Wincoop (2003), who report that "the average elasticity is respectively 4.8, 5.6 and 6.9 for 1-digit, 2-digit and 3-digit industries. For further levels of disaggregation the elasticities could be much higher, with some goods close to perfect substitutes. It is therefore hard to come up with an appropriate average elasticity." Anderson and van Wincoop (2003) consider a range of 5 to 10 to be reasonable based on a survey of empirical studies, although again the focus of these studies tends to be on many disaggregated categories of goods.

One problem for us is that the nontraded-traded distinction is even coarser than the 1-digit level studied by Hummels. Thus, the true elasticity is probably much lower. But how low? Some postulate a very low elasticity of substitution of 0.1; this figure was proposed by Burstein, Eichenbaum, and Rebelo (2005), but they admit that there is no empirical support for that choice and it is based on pure introspection. A range of 0.1 to 10 seems hopelessly wide for useful inference.

Most of the macro literature chooses a value in between. Stockman and Tesar (1995) calibrated this elasticity at 0.44 based on econometric evidence. Ruhl (2005) notes that the disagreement between the trade and macro literature poses a problem, but his theory is one that might explain the lower elasticities used in high-frequency macro analysis. As he sums up: "International real business cycle … modelers commonly use Armington elasticities around 1.5, though sensitivity analysis suggests values even lower than this may be appropriate… Not surprisingly, when empirical researchers have estimated the Armington elasticity from high frequency data they find small estimates that range from about 0.2 to 3.5."

The need for sensitivity analysis with respect to the elasticity of substitution is by now quite obvious. Judging from our survey of the literature, we concluded that 1.5 represents an upper bound for the parameter in the macro literature, and 0.5 a rough lower bound, at least if we restrict ourselves to parameters based on the majority of empirical evidence. In between is the benchmark Cobb-Douglas value of 1.0, the case studied by Reinhart, Rogoff and Spilimbergo (2003). Thus, we choose values from this range for our sensitivity analysis, focusing on five discrete choices for the elasticity, namely {0.5, 0.75, 1, 1.25, 1.5}.

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