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ABSTRACT

Did adoption of the gold standard exacerbate or diminish macroeconomic volatility? Supporters thought so, critics thought not, and theory offers ambiguous messages. A hard exchange-rate regime such as the gold standard might limit monetary shocks if it ties the hands of policy makers. But any decision to forsake exchange-rate flexibility might compromise shock absorption in a world of real shocks and nominal stickiness. A simple model shows how a lack of flexibility can be discerned in the transmission of terms of trade shocks. Evidence on the relationship between real exchange rate volatility and terms of trade volatility 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, and this historical pattern suggests that the interwar gold standard was a poor regime choice.

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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 changes 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 prewar and interwar periods. By indirect identification, we locate a structural change in open economy macroeconomic dynamics between the classical and interwar gold standard period.

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.

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 closely resembles this stylized model than 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, even fanciful, 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 sustainable.[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 have since been collected to 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. We show that the classical gold standard did not exacerbate real exchange rate volatility and it coped well with terms of trade shocks. The interwar gold standard could not handle these shocks very well, at a time when these shocks turned out to be quite large, and made real exchange rate volatility worse.

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[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 (2004a,b), 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 (2003).
[2] Figures derived from Alesina, Spolaore, and Wacziarg (2000), Maddison (1995), and Meissner (2005). 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 (2001), and López-Córdova and Meissner (2003). On the gold standard and bond spreads see Bordo and Rockoff (1996) and Obstfeld and Taylor (2003).

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 whilst interwar gold standard failed.

It if often argued that nominal flexibility in the world economy was giving way to increased price and wage rigidity in the early twentieth century. In this view, the gold standard was compromised as price adjustment shifted from the flexibility assumed by the classical economists to the stickiness emphasized by the Keynesians. But what evidence can be adduced? 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 cross-country and cross-regime evidence on shock absorption is a rare attempt at a comparative analysis of this kind 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 cross section of countries, Basu and Taylor (1999) found a mild increase in cyclicality of the real wage in the interwar period, 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 (2004) find evidence that deflation was not as damaging before World War One as in the inter-war period, and they suggest that a nearly vertical aggregate supply curve had become positively sloped by the 1920s as a result of increased nominal rigidity.

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 many 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 what fragmentary evidence we have, 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 clearly did not fall as rapidly as prices, an observation clearly at odds with the classical flexible-price model. Indeed, the non-neutral expansionary effect of devaluations in the setting of the 1930s has been shown in work on the 1930s 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 models 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.

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[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, Liu, and Phaneuf 2004).

Theoretical perspectives

We develop a simple, static, small open-economy model that extends the analysis in Reinhart, Rogoff, and Spilimbergo (2003). This classical model is designed to examine the impact of external shocks on small, open economies, and the interaction between nominal rigidity and the exchange rate regime. The key insight, common to many other models of this sort, is that nominal rigidity can lead the economy away from its first-best after an external shock, and policymakers can then employ a change in the nominal exchange rate to improve welfare and match the hypothetical flexible price equilibrium.

Model

The 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 a utility function

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

where C denotes consumption of the nontraded good, M denotes consumption of the imported good, and L denotes labor supply.[6]

The consumer's binding budget constraint is

$$p_C C + e p_M^* M = wL + e p_X^* X,$$

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 set by the government.

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

$$C = \gamma L,$$

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 $e p_M^* M = e p_X^* X$.

The model is solved and applied as follows. Once the world prices of the traded goods are revealed following a shock, the government makes a choice of e, and then consumers optimize and achieve some level of utility. Knowing all this beforehand, the government can attempt to set the optimal level of e to maximize consumer's utility.

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.)

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[6] 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.

To better understand the solution of model, we can examine the conditions for consumer maximization based on the Lagrangian

$$L=\left[\alpha C^{\rho}+(1-\alpha)M^{\rho}\right]^{\frac{1}{\rho}}-\frac{1}{\phi}L^{\phi}+\lambda\left[p_{c}C+ep_{M}^{*}M-wL-ep_{X}^{*}X\right].$$

The relevant first order conditions are

$$\left[\alpha C^{\rho}+(1-\alpha)M^{\rho}\right]^{\frac{1}{\rho}-1}\alpha C^{\rho-1}=\lambda p_{c}, \tag{1}$$

$$\left[\alpha C^{\rho}+(1-\alpha)M^{\rho}\right]^{\frac{1}{\rho}-1}(1-\alpha)M^{\rho-1}=\lambda ep_{M}^{*}, \tag{2}$$

$$L^{\phi-1}=\lambda w. \tag{3}$$

Dividing (1) by (2) and using the fact that $p_C = w/\gamma$:

$$C^{\rho}=M^{\rho}\left[\frac{1-\alpha}{\alpha}\right]^{\frac{\rho}{\rho-1}}\left[\frac{p_{c}}{ep_{_M}^{*}}\right]^{\frac{\rho}{\rho-1}}=\left[\frac{p_{X}^{*}X}{p_{_M}^{*}}\right]^{\rho}\left[\frac{1-\alpha}{\alpha}\right]^{\frac{\rho}{\rho-1}}\left[\frac{w}{ep_{_M}^{*}\gamma}\right]^{\frac{\rho}{\rho-1}}$$

Let $z = w/e$ denote the local wage measured in foreign currency. The first component of utility can be written simply as a function of z and exogenous variables and parameters:

$$U_{1}=\left[\alpha C^{\rho}+(1-\alpha)M^{\rho}\right]^{\frac{1}{\rho}}=\left[\frac{p_{X}^{*}X}{p_{_M}^{*}}\right]^{\rho}\left\{\alpha\left[\frac{1-\alpha}{\alpha}\right]^{\frac{\rho}{\rho-1}}\left[\frac{z}{p_{_M}^{*}\gamma}\right]^{\frac{\rho}{\rho-1}}+(1-\alpha)\right\}^{\frac{1}{\rho}} \tag{4}$$

Further calculations show that the shadow price is given by

$$\lambda=\frac{1-\alpha}{ep_{_M}^{*}}\left\{\alpha\left[\frac{1-\alpha}{\alpha}\right]^{\frac{\rho}{\rho-1}}\left[\frac{z}{p_{_M}^{*}\gamma}\right]^{\frac{\rho}{\rho-1}}+(1-\alpha)\right\}^{\frac{1}{\rho}-1}$$

Thus, by (3), we find

$$U_{2}=-\frac{L^{\phi}}{\phi}=-\frac{(\lambda w)^{\frac{\phi}{\phi-1}}}{\phi}=-\frac{1}{\phi}\left(\frac{z(1-\alpha)}{p_{_M}^{*}}\right)^{\frac{\phi}{\phi-1}}\left\{\alpha\left[\frac{1-\alpha}{\alpha}\right]^{\frac{\rho}{\rho-1}}\left[\frac{z}{p_{_M}^{*}\gamma}\right]^{\frac{\rho}{\rho-1}}+(1-\alpha)\right\}^{\left(\frac{1}{\rho}-1\right)\left(\frac{\phi}{\phi-1}\right)} \tag{5}$$

Adding (4) and (5) we can see that the consumer's utility $U=U(z;...)$ is 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. (Of course, in this particular setup, a 1% shock to the endowment of the export good is isomorphic to a 1% shock to the world price of the export good.)

How does the economy get to z^*? If wages are flexible, this is not a problem: the economy ends up at the first best, as is well known. If wages are sticky, the economy is at a constrained optimum; yet fortunately, the government can still adjust a flexible exchange rate to ensure that z attains its optimum value z^*, no matter where w is stuck.

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.

Three Cases

We apply the model to three cases of interest: perfectly flexible wages, perfectly sticky wages, and partially sticky wages. We consider the response of the economy with optimal policies to a standardized decline in the terms of trade, a 1% decline in the price of the export good.

CASE I: In the case of *flexible wages*, no matter what the level of the exchange rate e, the local-currency nominal wage adjusts to the first-best level $w = z^* e$. Here, the choice of exchange rate—and the exchange rate regime—is irrelevant, and welfare is always at the maximum attainable level. How will the adjustment occur? Because the terms of trade have fallen, the economy can now afford less of the importable M than before under balanced trade. Relatively speaking, the consumer must substitute C for M. To be willing to do that, at an optimum, the relative price of the C good must fall, so p_C and hence w must fall relative to the local-currency importable price ep_M^*. Thus, z^* will fall. Suppose $d \ln z^* = \eta d \ln p_X^*$ for some elasticity η. This says that when the export price falls 1%, the optimal z will fall η%. If e is unchanged, as in a fixed exchange rate regime, then the fall in w equals η%:

(I: Flexible w; Fixed e,): $$d \ln w = \eta d \ln p_X^* ;\ d \ln e = 0 .$$

More generally, even if the authorities adjust e, for reasons unexplored here, it makes no difference: w takes up the slack, and $d\ln w = d\ln z^* + d\ln e = \eta d\ln p_X^* + d\ln e$.

CASE II: In the case of *perfectly sticky wages*, w cannot adjust at all, and $d\ln w = 0$. So in this case, if we are to satisfy $d\ln z^* = d\ln w - d\ln e = \eta d\ln p_X^*$, then the authorities must set $d\ln e = -\eta d\ln p_X^*$. In the absence of wage flexibility, a flexible exchange rate serves as a shock absorber in the classic fashion:

(II: Fixed w, flexible e): $d\ln w = 0;\ d\ln e = -\eta d\ln p_X^*$.

CASE III: The preceding cases are those analyzed by Reinhart, Rogoff, and Spilimbergo (2003) for the Cobb-Douglas case (where $\rho = 0$). To extend the analysis to a situation of *partially sticky wages*, we now imagine that after any shock hits, domestic local-currency wages adjust by an amount less than that implied by perfect flexibility, but more than the zero implied by perfect stickiness. Specifically, suppose wages move by a fraction $(1-s)$ times the amount they would move under perfect flexibility, so that s (between 0 and 1) is an index of stickiness. In this case, whatever fraction of the adjustment of z is not met via wage adjustment, remains to be absorbed by an exchange rate adjustment:

(III: Partial flexibility): $d\ln w = (1-s)\eta d\ln p_X^*;\ d\ln e = -s\eta d\ln p_X^*$.

Clearly, I and II are just special cases of III, when the stickiness parameter takes the extreme value of 0 or 1. Case III is useful as it allows us to study the response of the economy under optimal policy when stickiness varies along a continuous range.

Calibration

To explore the implications of the model for optimal exchange rate policy, we simulated the response to a 1% drop in the world price of the country's exports. The benchmark parameters were 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 $\sigma = 1.5$. The choice of parameters is justified as follows.

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 much greater share of traded output in total output circa 1900 (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% nontraded 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. 2003). 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 out parameter choices, we discuss our choices at some length.

It has proven quite difficult for empiricists to pin down with accuracy the elasticity of substitution, especially at high levels of aggregation. Anderson (1998) stated 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 of values 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 reasonable based on a survey 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. The real elasticity is probably lower. But how low? Some postulate a very low elasticity of substitution of 0.1; this figure was proposed by Burstein et al.

(2003), 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 (2003) 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 this range values for our sensitivity analysis, focusing on five discrete choices for the elasticity, namely {0.5, 0.75, 1, 1.25, 1.5}.

Simulations

Since the optimal exchange rate policy is trivial (or immaterial) when wages are perfectly flexible, Figure 1 examines the more interesting extreme case of perfect stickiness, when $s = 1$. 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 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% nominal 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 depreciations are 0.54% nominal and 0.19% real (a real depreciation where the nominal devaluation dominates). Within the range of values considered falls the value of elasticity of substitution, which we define as $\sigma = \sigma_0$, where a terms of trade shock with optimal exchange rate policy causes neither real appreciation nor depreciation. Evidently, σ_0 is approximately equal to 0.75 with the model as calibrated here.

For intermediate degrees of wage stickiness, the implications are fairly obvious. The adjustment would take the form of a convex combination of an exchange rate movement (equal to the above adjustments with a weight s) and a wage 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 very low (well below 0.5) or very 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—either a small real appreciation or a small real depreciation. 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 Figure 1b, which may be compared with Figure 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 stuck 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.

The movements in the real exchange rate is much more volatile in this case (Figure 1b) than under optimal floating (Figure 1a). 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%. In absolute size, 1% fluctuations in the terms of trade cause real exchange rate fluctuations about 50% to 150% times larger in absolute size under stickiness and fixed rates than under flexibility or optimal floating.

These general implications are summarized in Figure 2 for the case when the elasticity of substitution is close to σ_0 (an assumption we will test). When wages and prices 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). When wages are stuck, the exchange rate must be unstuck to absorb the shock.

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 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.

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: (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) the extent of it only depends on the exchange rate regime only when nominal rigidities are present.

From Theory to Empirics: Evaluating the Classical and Interwar Gold Standards

The general lessons of these types 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) developed a comprehensive framework for examining the determinants of real exchange rate volatility. They used panel regressions to relate the volatility of the real exchange rate to independent variables familiar from the gravity approach: "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 were of the form:

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

where, $qvol_{ijt}$ is the real exchange rate volatility (standard deviation of logged values) 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) used theory to explain why one should also include a measure of the trade share (or "trade openness") of the economy an important additional control variable (akin to the trade weight α in our model). His estimating equation was:

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

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

Our model provides two reasons to further augment the prevailing approach estimating equations such as (7) and (8).

A first refinement to these empirical designs is suggested by equation (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 (Figure 2). This will turn out to be very important empirically below, where we estimate variants of a benchmark econometric model of the form

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

where the unit of observation in our data is a non-overlapping 5-year window of annual data for each pair; GS_{ijt} is an indicator variable for gold standard adherence for country-pair *i-j* (equals 1 if both were on the gold standard, averaged over five years); and $TOTvol_{ijt}$ is the terms-of-trade volatility (again, standard deviation of logged values) 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), to match the qualitative predictions of our model in Figure 2. Hence we set

$$\beta_4 = \beta_{40} + \beta_{41} GS_{ijt}, \qquad (9)$$

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

A second refinement to these empirical designs is suggested by our model of optimal monetary policy, where the nominal exchange rate reacts to shocks as part of the shock absorption process. Thus, in equations like (7), (8), or (9), it would appear questionable, a priori, to treat nominal exchange rate volatility (*evol*) as exogenous: countries buffeted by bigger external shocks might be expected to pull the levers of exchange rate policy more aggressively. We take steps below to address this endogeneity problem, although we find that our results are not greatly affected.

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. If all other effects are properly controlled for, we can treat shifts in β_4 from one era to the next as evidence structural changes. We still need to control for the direct effects of gold standard regime, nominal exchange rate volatility, openness and bilateral trade, as per the previous literature (and to avoid problems of trade endogeneity, we perform IV estimation using distance as an instrument for trade, or we use distance directly as a control variable in OLS estimation). Finally, we also need to worry about the endogeneity of nominal exchange rate volatility.

Data

Our dataset includes observations for the period from 1870 to 1939. Throughout, we will estimate two parallel regressions: the first includes only observations from before 1914, the second includes only observations from after 1918, i.e., we omit observations corresponding to World War One 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. To construct real and nominal exchange rate volatilities we first obtained the logarithm of the first differences of bilateral exchange rates and then tabulated standard deviations of the resulting observations over five-year windows.

As we can see from Table 2 the volatility of both nominal and real exchange rate changed markedly after World War One. Average real exchange rate volatility rose by an order of magnitude, from 0.057 to 0.512. Its standard deviation also increased from 0.042 to 1.413, translating into an increase in the coefficient of variation from .74 to 2.77. Locating the underlying causes of these changes is a major goal of this paper. We can immediately see that a similar pattern is observed for nominal exchange rate volatility, suggesting one possible explanatory factor.

In the basic specification of our regression the gold standard indicator variable was set equal to one for those years when both countries *i* and *j* were on the gold standard. Approximately 60% of the country-pair observations in our dataset were on the gold standard before World War One. This number decreases to 17% for the post-1918 sample, as expected—the interwar gold standard was fragile and short-lived. As a robustness check we also constructed two other gold standard dummies. The first was equal to the percentage of years in the five-year windows when both countries were on the gold standard. The second was set to one if both countries were on the gold standard at the beginning of a five-year window. These produced materially similar results (see below).

We defined the terms of trade for each country in the sample as the relative price of exports in terms of imports, reported by Hadass and Williamson (2003). Bilateral "relative" terms of trade volatility was then computed as the standard deviation of the ratio of terms of trade of countries *i* and *j* over five-year windows. That is, as in many theoretical models, 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 $P_i^X / P_j^X = (P_i^X / P^w)/(P_j^X / P^w)$, and it is this last expression we use for each pair.

For the countries in our dataset the average relative terms of trade volatility doubled from 0.081 in the pre-1914 sample to 0.157 in the post-1918 sample. The standard deviation similarly increased from 0.051 to 0.087. This is also unsurprising: it is well known that the amplitude of terms of trade shocks grew enormously in the interwar period (Kindleberger 1973).

We also constructed a measure of openness for each country as the ratio of trade (exports plus imports) over GDP. In our regression analysis we used a measure of average openness, which is 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, 1992b, 1993a, 1993b).

Results

The dependent variable in all of our regression specifications is the volatility of the real exchange rate. As a first step we would like to determine that the gold standard did have a significant impact on real exchange rate volatility. Our first specification includes the gold standard indicator variable, nominal exchange rate volatility, and our measures of openness and distance as independent variables, akin to equation (8). We expect that most of the variation in the real exchange rate will be attributable to nominal exchange rate volatility. Including nominal exchange rate volatility as one of our independent variables also allows us to isolate the gold standard's auxiliary effect. We are not primarily interested in the effects of the openness and trade variables, but include them in all of our specifications as control variables.

The results of our initial specification are reported in the first two columns of Table 3. Interestingly, *including the country fixed effects*, this specification captures 98.5% of the variation for the post-1918 period, but only 55.8% of the variation for the pre-1914 period. There is evidently much more "within" variation in the interwar panel, whereas in the prewar panel the fixed effects do a good job of capturing most of the dominant "between" variation.

As expected, in both the pre-1914 and post-1918 regressions nominal exchange rate volatility explains much of the variation in real exchange rate volatility: the coefficients on the nominal exchange rate are positive and significant. The estimated coefficient for pre-1914 sample is 0.397. Sample standard deviations for the real and nominal exchange rates for this period are 0.042 and 0.050, respectively. Hence, if nominal exchange rate volatility increased by one standard deviation, our specification implies that real exchange rate volatility would have increased by 0.47 standard deviations. The effect is even more pronounced in the post-1918 period. Given the coefficient on the nominal exchange rate coefficient (1.223) and the standard deviation of nominal exchange rate volatility (0.923), we can see that a one standard-deviation increase in nominal exchange rate volatility implies a 0.98 standard-deviation increase in real exchange rate volatility.

Before 1914 the "pure" gold standard effect reduced real exchange rate volatility as the estimated coefficient on the gold standard indicator is –0.009. The mean value for the real exchange rate volatility for that period is 0.056, implying that countries on the gold standard had on average 16% less real exchange rate volatility. It bears repeating that this dampening effect of the gold standard was in addition to its effect on nominal exchange rate volatility (which is already controlled for). It may be due to the gold standard's stimulation of trade (Estevadeordal, Frantz, and Taylor 2003; Flandreau and Maurel 2002; López-Córdova and Meissner, 2003).

After 1918, the gold standard indicator's coefficient becomes *positive*. Adhering to the gold standard added approximately 10% to the volatility of real exchange rates during that period (the estimated coefficient is 0.039 and the mean real exchange rate volatility is 0.40). How is it that the gold standard reduced real exchange rate volatility during the pre-World War One years but greatly exacerbated it once the war was over? This finding is consistent with increased nominal rigidities and violations of the gold standard rules.

However, we also suspect that increased terms of trade volatility significantly contributed to this story. In order to test this hypothesis we include our measure of relative terms of trade volatility and an interaction term for the gold standard and relative terms of trade volatility as independent variables. With the additional independent variables, the adjusted R-squared slightly increases to 0.587 in the pre-1914 regression and to 0.998 for the post-1918 sample. Most of the results look similar to our first-pass estimates, but with some notable exceptions.

The coefficient on terms of trade volatility is negative and insignificant (using a standard 5% level of significance threshold) for both the pre-1914 and post-1918 sample (–0.096 and –0.083 respectively). The coefficient on the *interaction* terms for the gold standard and terms of trade volatility is positive but insignificant for the pre-1914 sample (+0.118); but it is positive and significant for the post-1918 sample (1.407).

What do these results tell us? First, absent any reliable estimates of the elasticity of substitution from the literature, we can use always use the model to identify this parameter. Recall 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 (cf. Figures 1). 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 set close to σ_0, justifying our earlier assumption that this was the case (e.g., when laying out the qualitative story in Figure 2).

However, of greater interest to us is the way the result start to deviate in the postwar period depending on whether countries peg or float. These striking results suggest 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 where 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 proves 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 development using quantitative methods.

The results indicate that for those countries on the gold standard in the pre-World War One years, a one standard deviation increase in the terms of trade volatility contributed to an increase of 0.027 standard deviations in real exchange rate volatility. For countries that had flexible exchange rates at that time the equivalent result is a reduction of 0.12 standard deviations. In other words, the logic of our model is confirmed. For the post-1918 sample we get the following estimates: an increase of 0.08 standard deviations for gold standard countries and a reduction of 0.005 standard deviations for countries that used flexible exchange rates. It is interesting to note here that from prewar to interwar, the shock absorbing capacity of flexible rates seemed to decrease, and gold standard adherence seem to worsen the pass-through from terms of trade shocks to real exchange rate shocks.

These differences between the two epochs are highlighted graphically in Figure 3. The similarity to Figure 2 is striking. Floats in both eras absorbed shocks well, as the model would have predicted. As for pegging, the gold standard also absorbed shocks very well prior to 1914, but the interwar economy was a poor shock absorber: increases in terms of trade volatility resulted in increases in real exchange rate volatility. In our model, as we saw in Figure 2, this kind of steep response is only seen in one case: *fixed regimes with stickiness*. This is the central result in our paper and is consistent with the oft-repeated—but hitherto unsubstantiated—conventional 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.

Another interesting result, though, is the change in sign of the gold standard dummy coefficient in post-1918 estimation. After accounting for terms of trade volatility, the coefficients on the gold standard indicators become negative and significant for *both* periods. The estimates are -0.023 and -0.085 for the pre-1914 and post-1918 samples, respectively. Thus, the gold standard was on average associated with a 40% and 17% reduction in real exchange rate volatility during the respective periods. This result has interesting implications when we consider the net effects of the gold standard, terms of trade volatility, and their interaction over time.

Before 1914, a country adopting the gold standard and simultaneously experiencing a one standard deviation *increase* in its terms of trade volatility would have seen its real exchange rate volatility fall by 52% of a standard deviation. On the contrary, the same country after World War

One would have seen its real exchange rate volatility increase by over 2% of a standard deviation. This implies that as a fixed regime, the gold standard carried a much higher price in terms of real economic destabilization in the inter-war milieu, suggesting that much of the gold standard's "optimality" may have been dissipated as economies and institutions evolved in such a way as to make it more difficult to smooth external shocks (McKinnon, 1963).

Robustness checks

As we have noted, one potential problem is that nominal exchange rate volatility (*evol*) enters on the right hand side and is treated as exogenous. However, this is at odds with our model where a nominal exchange rate response is endogenous, and is part of the optimal response under floating to exogenous terms of trade shocks. We would prefer to include only the *exogenous* component of *evol* in (9), to control for, say, policy errors or other sources of exchange rate volatility that could affect the real exchange rate independent of terms of trade shocks.

To address the concern that endogenous components in *evol* might be biasing our results, we construct a predicted measure of exchange rate volatility, by estimating the equation

$$evol_{it} = \begin{cases} \alpha_{0i} + \alpha_{0j} + \alpha_1 TOTvol_{ijt} + \eta_{ijt} & \text{if } GS_{ijt} = 0 \\ 0 & \text{if } GS_{ijt} = 1 \end{cases}$$

where, under a floating regime only, exchange rate volatility responds to terms of trade volatility. In addition, there are country specific volatility terms to allow for any other idiosyncratic differences in monetary policy. We then set

$$evolhat_{it} = \begin{cases} \eta_{ijt} & \text{if } GS_{ijt} = 0 \\ 0 & \text{if } GS_{ijt} = 1 \end{cases}$$

and use this residual measure in place of $evol_{it}$ when estimating regression (9).

The results are shown in Table 4. The principal finding, that the interaction of the gold standard with terms of trade volatility sharply increased after 1914 is unaffected by this procedure, and the qualitative results still match Table 3.

We have also estimated the effect of the gold standard on real exchange rate volatility using alternative definitions of the gold standard variables as well as different control variables and alternative estimation techniques. In all cases the estimates had the same signs and similar magnitudes as in our preferred specifications. The results are reported in Tables 5 through 7.

We start with two alternative definitions of the gold standard variable. We set the gold standard indicator equal to one if both countries were on the gold standard at the beginning of a five-year window. We also calculated the percentage of years that both countries were on the gold standard. The results of these estimations are reported in Table 5. In both cases nominal exchange rate volatility is positive and highly significant, and the estimated coefficients correspond very closely to ones from our preferred specification. We conclude that alternative definitions of the gold standard do not affect the results and use our initial definition of the gold standard dummy in all our following estimations.

Our next step was to check if our choice of control variables has an impact on the results. In the reported specification we use a measure of distance as a proxy for trade. Here for each pair we calculate average bilateral trade distances over five-year windows and then perform estimations using this measure. Previous studies have shown that both currency unions and the gold standard have significant effects on trade. In order to avoid problems associated with the possible endogeneity of trade, we use IV estimation with distance, common border, island and landlocked variables as instrumental variables for trade. The results are reported in Table 6. The shift to IV estimation does not materially change the results. After accounting for the terms of trade volatility we get the same change of sign associated with the gold standard indicators for the post-1918 sample. The coefficients are significant and very similar to the reported results from our preferred specification.

Finally, we estimate using country pair fixed effects instead of just country effects. The results are reported in Table 7. Once again, the estimated coefficients are significant and correspond closely to the previously reported results.

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 rare 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 rigidity can have implications for optimal monetary policy, as can be seen in a simple classical model (or in many 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 (at least based on state-of-the-art calibration practices) 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 Figure 3, suggests that it did.

Two caveats must be offered. First, our model is an important guide; but is a simplification, as are all economic models. 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 Figure 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 toy 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 end the world's most durable fixed exchange rate regime.

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Table 1
Countries in the Sample

Argentina	Denmark	Italy	Russia†
Australia	Egypt	Japan	South Africa
Austria†	Estonia*	Latvia*	Spain
Belgium	Finland	Lithuania*	Sweden
Bolivia	France	Luxembourg	Switzerland
Brazil	Germany	Mexico	Turkey†
Bulgaria	Greece	The Netherlands	The United Kingdom
Canada	Hungary*†	New Zealand	The United States
Chile	Iceland	Norway	Uruguay
China	India	Peru	Venezuela*
Colombia	Iran*	Portugal	
Czechoslovakia*†	Ireland*	Rhodesia	

* Interwar sample only.
† 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.

Table 2
Summary Statistics

(a) Initial Specification, Full Sample

Pre-1914			
Variable	*Observations*	*Mean*	*Standard Deviation*
Nominal exchange rate volatility	456	0.035	0.050
Gold standard indicator	456	0.603	0.490
Average openness	456	0.001	0.001
Distance (logged)	456	7.180	1.227
Real exchange rate volatility	456	0.056	0.042
Post-1918			
Variable	*Observations*	*Mean*	*Standard Deviation*
Nominal exchange rate volatility	515	0.362	0.923
Gold standard indicator	515	0.171	0.377
Average openness	515	0.001	0.001
Distance (logged)	515	7.707	1.116
Real exchange rate volatility	515	0.401	1.148

(b) Regressions With Terms Of Trade, Restricted Sample

Pre-1914			
Variable	*Observations*	*Mean*	*Standard Deviation*
Nominal exchange rate volatility	294	0.041	0.003
Gold standard indicator	294	0.520	0.500
Relative terms-of-trade volatility	294	0.081	0.051
Gold standard-TOT volatility interaction	294	0.038	0.052
Average openness	294	0.001	0.001
Distance (logged)	294	7.490	1.100
Real exchange rate volatility	294	0.057	0.042
Post-1918			
Variable	*Observations*	*Mean*	*Standard Deviation*
Nominal exchange rate volatility	234	0.433	1.114
Gold standard indicator	234	0.115	0.320
Relative terms-of-trade volatility	234	0.157	0.088
Gold standard-TOT volatility interaction	234	0.009	0.027
Average openness	234	0.001	0.001
Distance (logged)	234	8.107	0.962
Real exchange rate volatility	234	0.512	1.413

Table 3
Estimation Results

Estimation Period	Observations	Adjusted R^2	Intercept	NER volatility	Gold standard	Openness	Distance	TOT volatility	GS-TOT interaction
Pre-1914	456	0.5613	0.098	0.397	-0.009	-2.239	0.001		
			(4.61)	(4.54)	(-2.02)	(-1.75)	(0.24)		
Post-1918	515	0.9982	-0.049	1.223	0.039	13.044	0.006		
			(-0.69)	(87.02)	(2.70)	(1.35)	(0.67)		
Pre-1914*	294	0.5871	0.118	0.416	-0.013	-2.584	-0.001		
			(5.69)	(4.45)	(-2.43)	(-1.52)	(-0.59)		
Pre-1914	294	0.5964	0.124	0.421	-0.023	-2.436	-0.001	-0.096	0.118
			(5.83)	(4.44)	(-2.49)	(-1.48)	(-0.55)	(-1.73)	(1.86)
Post-1918*	234	0.9985	-0.128	1.267	0.031	1.170	-0.011		
			(-1.76)	(225.79)	(2.30)	(0.22)	(-1.67)		
Post-1918	234	0.9991	-0.116	1.268	-0.085	1.963	-0.012	-0.083	1.407
			(-1.59)	(237.73)	(-2.62)	(0.36)	(-1.77)	(-1.25)	(3.51)

* results for the restricted sample appearing in the subsequent row.

Table 4
Estimation Results Using Residual Measure of Exchange Rate Volatility

Estimation Period and Fixed Effects Used for Predicting NER Values	Observations	Adjusted R^2	Intercept	Predicted NER volatility	Gold standard	Openness	Distance	TOT volatility	GS-TOT interaction
Pre-1914	291	0.5456	0.096	0.179	-0.015	-3.013	0.001		
			(4.05)	(4.12)	(-2.43)	(-1.62)	(0.37)		
Post-1918	234	0.9980	-0.089	1.278	0.047	-5.681	-0.016		
			(-1.17)	(196.89)	(3.34)	(-0.88)	(-2.15)		
Pre-1914, none	291	0.4418	0.019	0.446	-0.018	-4.328	0.006	-0.459	0.332
			(1.49)	(6.96)	(-2.34)	(-2.90)	(3.11)	(-4.68)	(3.88)
Pre-1914, time fixed effects	291	0.4808	0.015	0.415	-0.018	-4.479	0.006	-0.420	0.315
			(1.01)	(6.81)	(-1.95)	(-2.77)	(3.10)	(-4.43)	(3.43)
Pre-1914, country fixed effects	291	0.5771	0.111	0.309	-0.028	-2.796	0.001	-0.313	0.273
			(4.58)	(4.09)	(-3.10)	(-1.60)	(0.35)	(-3.25)	(3.37)
Pre-1914, time/country fixed effects	291	0.6262	0.137	0.246	-0.025	-2.719	0.001	-0.239	0.239
			(5.54)	(3.52)	(-2.44)	(-1.44)	(0.64)	(-2.45)	(2.99)
Post-1918, none	234	0.9976	0.042	1.284	-0.071	4.973	-0.009	-0.196	1.483
			(0.95)	(237.76)	(-2.63)	(0.95)	(-1.67)	(-3.33)	(4.68)
Post-1918, time fixed effects	234	0.9976	0.042	1.282	-0.075	3.280	-0.009	-0.156	1.422
			(0.92)	(230.20)	(-2.81)	(0.62)	(-1.73)	(-2.22)	(4.52)
Post-1918, country fixed effects	234	0.9981	-0.074	1.282	-0.090	-3.773	-0.017	-0.203	1.568
			(-0.96)	(197.18)	(-2.98)	(-0.59)	(-2.13)	(-2.39)	(4.22)
Post-1918, time/country fixed effects	234	0.9983	0.024	1.281	-0.100	-8.674	-0.016	-0.142	1.294
			(0.35)	(201.91)	(-3.68)	(-1.41)	(-2.29)	(-1.32)	(3.94)

Table 5
Alternative Gold Standard Definitions

Estimation Period	Observations	Adjusted R^2	Intercept	NER volatility	Initially on GS	Openness	Distance	TOT volatility	GS-TOT interaction	GS percent.	GS-TOT interaction
Pre-1914	456	0.5565	0.090	0.423	-0.003	-2.318	0.001				
			(4.10)	(4.80)	(-0.57)	(-1.82)	(0.33)				
Pre-1914*	294	0.5778	0.108	0.444	-0.006	-2.907	-0.001				
			(5.07)	(4.67)	(-0.96)	(-1.65)	(-0.46)				
Pre-1914	294	0.5743	0.115	0.452	-0.016	-2.584	-0.001	-0.105	0.143		
			(5.24)	(4.75)	(-1.84)	(-1.54)	(-0.46)	(-2.17)	(2.49)		
Post-1918	515	0.9877	-0.097	1.223	0.044	16.626	0.007				
			(-1.07)	(94.50)	(1.62)	(1.59)	(0.78)				
Post-1918*	234	0.9981	-0.140	1.262	-0.035	1.669	-0.010				
			(-2.03)	(230.52)	(-2.61)	(0.33)	(-1.59)				
Post-1918	234	0.9973	-0.160	1.266	0.045	2.622	-0.007	-0.095	-1.126		
			(-2.32)	(239.83)	(1.68)	(0.53)	(-1.02)	(-1.48)	(-3.84)		
Pre-1914	456	0.5528	0.092	0.413		-2.283	0.001			-0.005	
			(4.02)	(4.73)		(-1.80)	(0.32)			(-1.24)	
Pre-1914*	294	0.5814	0.110	0.433		-2.771	-0.001			-0.008	
			(4.94)	(4.65)		(-1.58)	(-0.45)			(-1.82)	
Pre-1914	294	0.5802	0.117	0.445		-2.633	-0.001	-0.096		-0.016	0.110
			(5.13)	(4.75)		(-1.52)	(-0.48)	(-1.86)		(-2.33)	(1.75)
Post-1918	515	0.9911	-0.095	1.229		13.883	0.008			0.087	
			(-1.23)	(93.59)		(1.43)	(0.92)			(3.70)	
Post-1918*	234	0.9976	-0.134	1.269		1.923	-0.010			0.055	
			(-1.82)	(227.16)		(0.36)	(-1.54)			(2.93)	
Post-1918	234	0.9962	-0.122	1.269		1.727	-0.011	-0.035		-0.026	0.983
			(-1.64)	(232.07)		(0.32)	(-1.68)	(-0.50)		(-0.64)	(1.79)

* results for the restricted sample appear in the subsequent row.

Table 6
Alternative Controls

Estimation Period	Observations	Adjusted R^2	Intercept	NER volatility	Gold standard	TOT volatility	GS-TOT interaction	Openness	Bilateral trade	Instrumented trade
Pre-1914	294	0.5887	0.112	0.418	-0.023	-0.095	0.117	-2.497	0.001	
			(11.51)	(4.43)	(-2.47)	(-1.72)	(1.85)	(-1.42)	(0.29)	
Post-1918	234	0.9972	-0.211	1.269	-0.079	-0.083	1.322	-1.343	0.010	
			(-3.98)	(218.28)	(-2.49)	(-1.25)	(3.38)	(-0.19)	(1.48)	
Pre-1914	294	0.5873	0.109	0.417	-0.022	-0.092	0.111	-3.998		0.002
			(9.54)	(4.43)	(-2.44)	(-1.68)	(1.75)	(-0.93)		(0.45)
Post-1918	234	0.9936	-0.230	1.273	-0.064	-0.039	1.272	-33.612		0.048
			(-4.38)	(200.96)	(-1.91)	(-0.51)	(3.22)	(-1.43)		(1.75)

Table 7
Country Pair Effects

Estimation Period	Observations	Adjusted R^2	Intercept	NER volatility	TOT volatility	GS-TOT interaction	Openness
Pre-1914	294	0.6513	0.386	-0.026	-0.098	0.134	-9.938
			(6.51)	(-2.65)	(-1.46)	(1.59)	(-1.44)
Post-1918	234	0.9993	1.271	-0.112	-0.146	1.657	30.342
			(181.59)	(-2.31)	(-1.64)	(2.98)	(1.79)

Figure 1(a)
Model Predictions with Sticky Wages

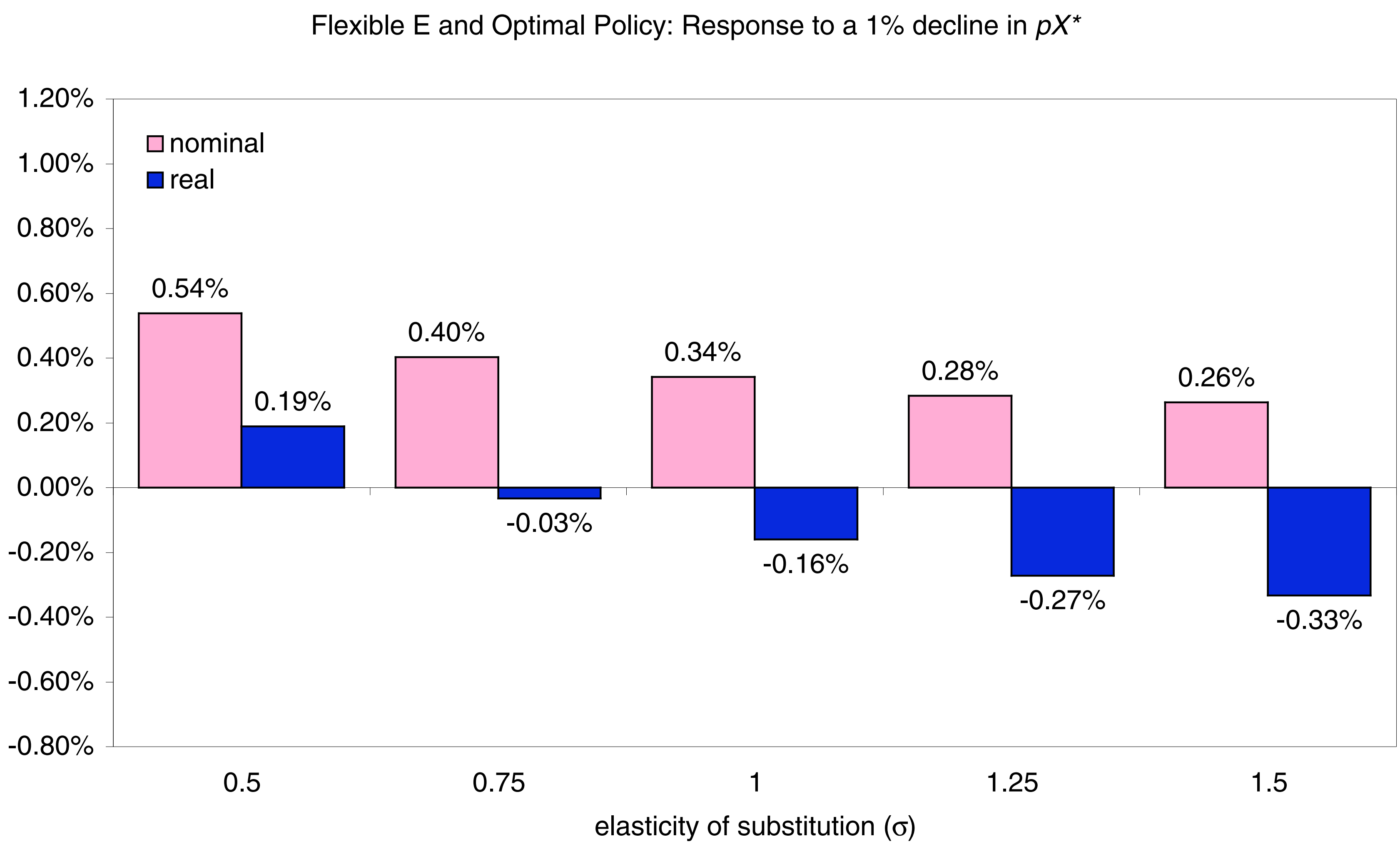

Figure 1(b)
Model Predictions with Sticky Wages

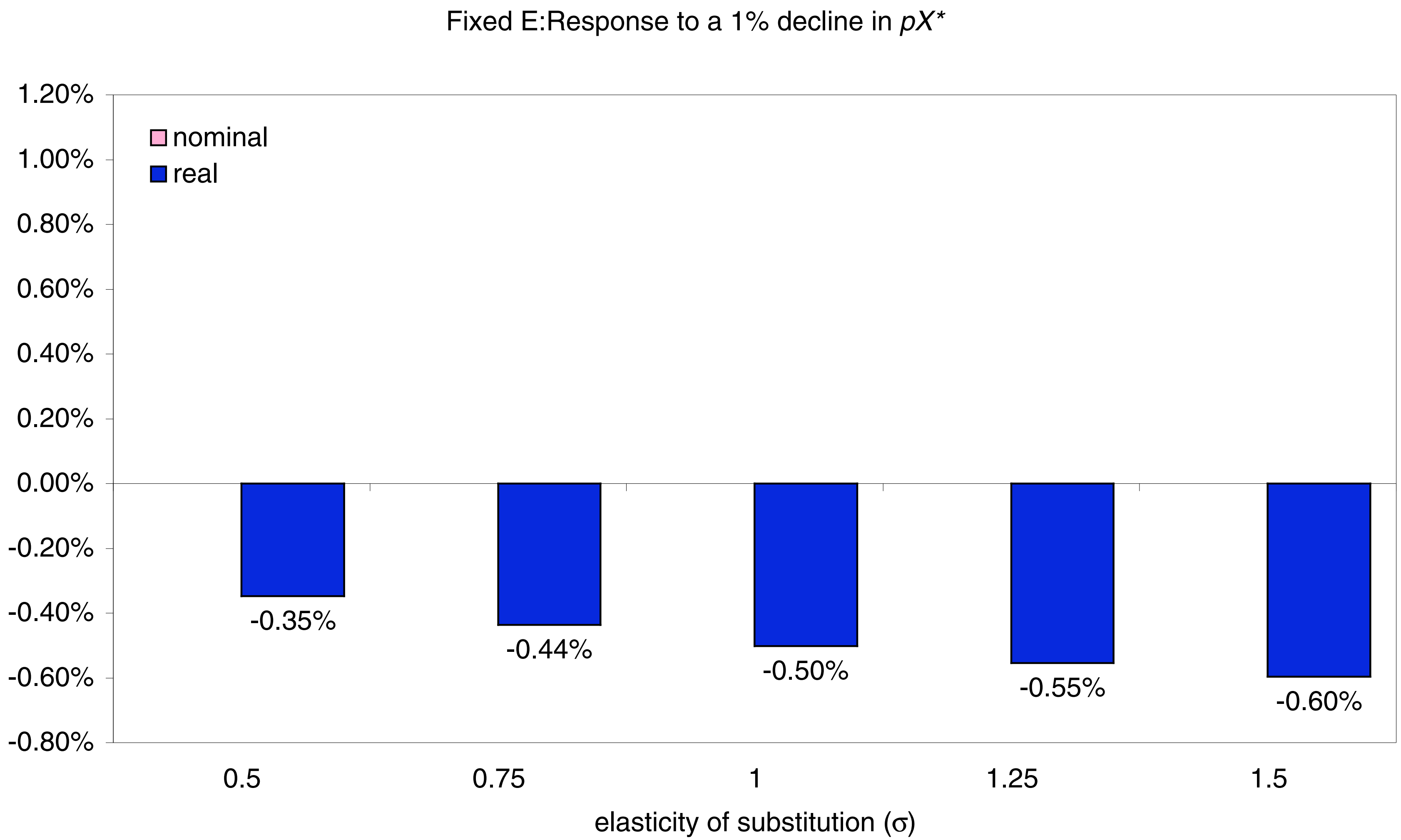

Figure 2
Model Predictions: RER Volatility versus TOT Volatility

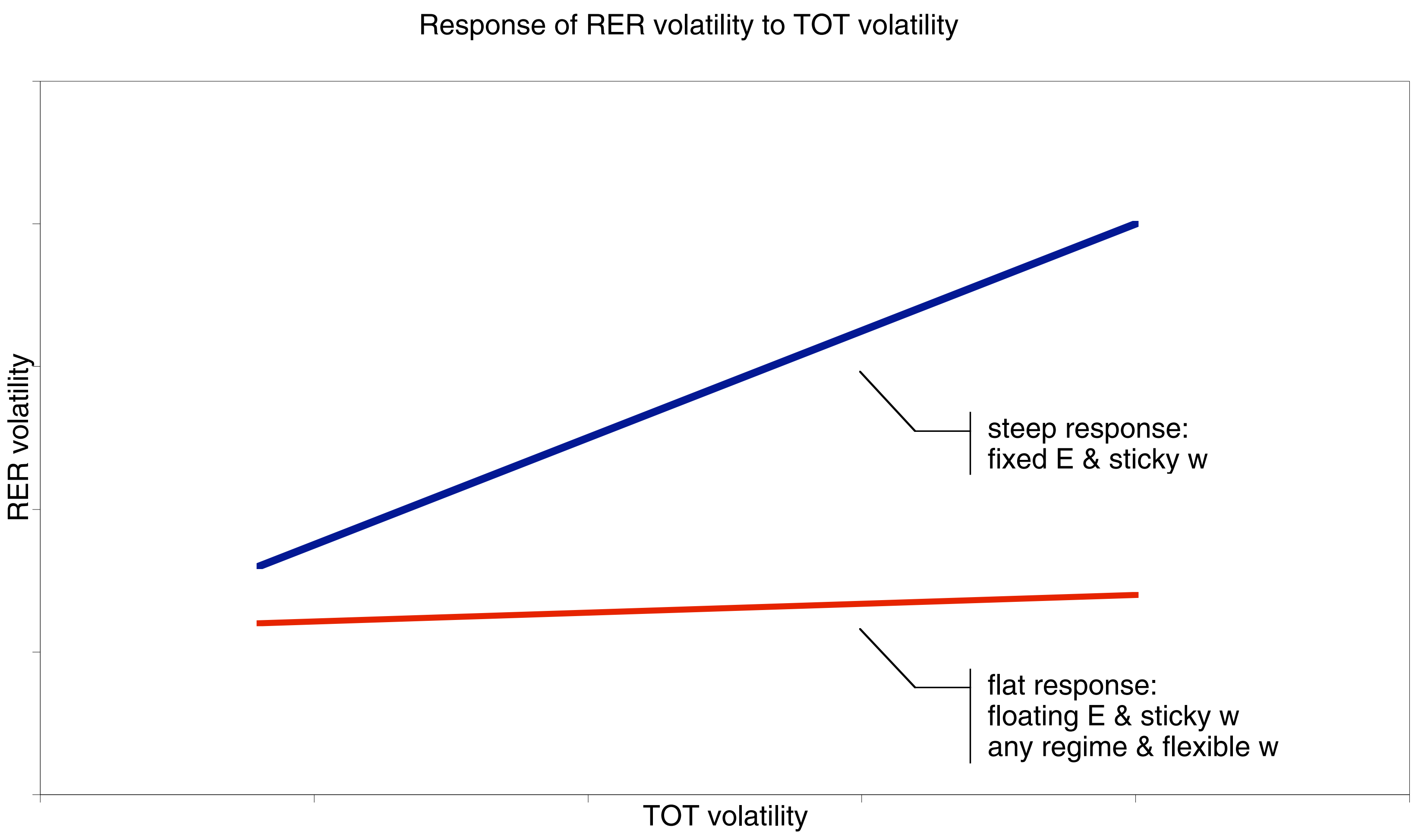

Figure 3
Data: RER Volatility versus TOT Volatility