Real Exchange Rate Volatility and Economic Openness: Theory and Evidence

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Abstract

This paper relates the volatility of the (trade-weighted) effective real exchange rate to the degree of trade openness of an economy. The theoretical part presents an intertemporal monetary model with nominal labor (factor) market rigidities. Both monetary and aggregate supply shocks are shown to imply a (non-linear) inverse relationship between the import share of an economy and the volatility of its real exchange rate. Empirical evidence on a cross-section of 54 countries confirms this relationship: Difference in trade openness explain a large part of the cross-country variation in the volatility of the effective real exchange rate.

JEL Classification: F3, F4

Keywords: Real effective exchange rates, volatility, nontradeables

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1 Introduction

Eliminating real exchange rate volatility motivates the move to a common European currency area. Its economic benefits have often been evaluated against the alternative scenario of free floating exchange rates in an fairly integrated European capital and product market. But how are trade integration and openness related to real exchange rate volatility? Does increasing economic integration provide more stable real exchange rates even in the absence of a monetary union? In spite of the policy relevance of this iusse, surprisingly little is known about the determinants of real exchange rate volatility. Supporters of EMU for example point to large real exchange rate volatility of the DM/Dollar rate or Yen/Dollar rate as the alternative to a common Euro currency.[1] However, both these exchange rates are intercontinental exchange rates and therefore correspond to a relatively low degree of underlying trade integration. We argue on theoretical and empirical grounds that economic openness and real exchange rate volatility are inversely related. A high degree of trade integration tends to provide relatively stable real exchange rates, while intercontinental exchange rate with low degrees of underlying integration are extremely volatile.

The conventional wisdom relates real exchange rate movements to monetary and aggregate supply shocks in a sticky price environment. Following Hau (1999) and Obstfeld and Rogoff (1999) we use a structural prepresentation of nontraded goods to derive the response of the real exchange rate as a function of the openness of the economy. An important result is that nontraded goods create an *exchange rate magnification effect*: Real or monetary shocks imply real exchange rate movements which decrease in the openness of the economy. The intuition for this effect is that a monetary equilibrium requires a larger nominal exchange rate change if the relative price level adjustment depends on the exchange rate pass-through for an economy with fewer tradeables. Real exchange rate volatility is thus structurally linked to openness.[2]

The main contribution of this paper is to provide evidence on the predicted linkage. Two

[1] See for example Wyplosz (1997). Padoa-Schioppa (1995) affirms that trade integration is no remedy to the incompatibility of fixed exchange rates, free capital movement and independent national monetary policies often termed the 'inconsistent trinity'. But even if this is correct, the 'consistent trinity' of flexible exchange rates, free capital movement and independent monetary policies may be a much more attractive alternative if there exists a structural link between high trade integration and low volatility.

[2] Our distinction between traded and nontraded goods is based on the representation of this good in the foreign countries conumption basket as opposed to a technological definition of transportability. Large closed economies might have as many transportable goods in their consumption basket as small open economies, but tend to consume fewer foreign imports. Openness in our sense is suitably captured by the import share of GDP.

aspects of our statistical approach deserves to be highlighted. Since monetary models of the exchange rate perform poorly for short horizons, we measure the exchange rate volatility at low frequencies based on changes over three years.[3] Second, all volatility measures are based on effective (trade-weighted) exchange rates. Previous work was frequently based on bilateral US dollar exchange rate which can be of little relevance if the country in question does not have the US as its predominant trading partner and vice versa.[4] By contrast the effective exchange rate is the statistical equivalent of the exchange rate in a two country model where the foreign countries are summarized in a hypothetical 'rest of the world country'. The regression analysis starts from a cross-section of 54 countries. We find a significant negative relationship between openness and volatility.

But since openness governs only the exchange rate magnification effect of any given relative supply or monetary shock, it seems reasonable to concentrate the analysis on the OECD subsample for which we can assume that relative shocks are of similar magnitude. For the OECD subsample, the inverse of the import share alone explains almost 50 percent of the cross-country variation in the long-run volatility of the real effective exchange rate. We also find that the openness-volatility linkage is robust to various control variables, for example per capita income, average inflation, central bank independence and exchange rate regime choice.

In addition, we explore three alternative explanations for the openness-volatility linkage. First, we examine the reverse causality from real exchange to openness. A larger empirical literature has tried to identify exchange rate risk as a trade impediment. Following Romer (1993) we use the land area of a country as a suitable exogenous instrument for openness. A re-estimation of the volatility-openness regression with land area as instruments does not change the coefficient estimates and provides evidence against the risk-trade channel. Second, the presented evidence might be simply based on the failure of the law of one price and unrelated to nontradeables. If law of one price deviations are related to distance (Engel and Rogers, 1996) and openness is related to country size and distance, we might pick up the failure of the law of one price for tradeables. We show that this interpretation is incorrect, because distance related deviations from the law of one price for tradeables should be detectable primarily in

[3]Compare Bergin and Feenstra (1999) for a recent discussion of how staggered contracts can imply considerable nominal persistence. Here we simply assume long-lived factor price (wage) contracts.

[4]An example is Engel (1999). Using bilateral real dollar exchange rates in a volatility decompostion, he finds a role of relative nontradeable prices only for Canada, but not for various European countries. This is not surprising since only Canada and the US are each others predominant trading partners.

high frequency data. However, our structural volatility-openness linkage becomes weaker as we look at quarterly or yearly volatility measures. Third, the openness-volatility linkage might simply result from a closer comovement of domestic and foreign monetary shocks for more open economies. We reject this explanation because relative price level volatility is measure at the same low frequencies is uncorrelated with openness.

The following section presents the dynamic two-country model. Section 3 describes the dynamic steady state solution of the model (proposition 1), log-linearizes all first-order conditions (proposition 2) and summarizes the implications for exchange rates (propositions 3 and 4). The empirical part discusses the data in section 4.1 and the basic results in section 4.2. Alternative explanations of are discussed in section 5. Section 6 concludes.

2 The Model

The model is based on Hau (1999). The only new element is that we include supply shocks in our analysis. In contrast to Obstfeld and Rogoff (1999) we do not introduce the parameter for economic openness in the household utility function, but introduce nontradeability as a simple restriction on the foreign consumption basket. This makes a comparative statics exercise in openness utility independent.

Let there be two countries H (home) and F (foreign) of identical size, in which households provide production inputs (factors) for a continuum of domestic firms.[5] Households monopolistically supply a single factor and firms are monopolistic producers of a differentiated product. Let the index $i \in [0,1]$ represent households and their factors and a second index $z \in [0,1]$ firms and their products. Home country H is composed of households on the interval $[0, \frac{1}{2}]$ and the foreign country F is composed of the household set $[\frac{1}{2}, 1]$. Similarly, firms with $z \in \mathcal{H} \equiv [0, \frac{1}{2}]$ are located in country H and firms with $z \in \mathcal{F} \equiv [\frac{1}{2}, 1]$ are located in country F. We assume an equal share 2η of firms in each country produce nontradeables, which we group in subsets $\mathcal{H}^N \equiv [0, \eta]$ and $\mathcal{F}^N \equiv [1-\eta, 1]$. All remaining products $z \in \mathcal{H}^T \equiv [\eta, \frac{1}{2}]$ and $z \in \mathcal{F}^T \equiv [\frac{1}{2}, 1-\eta]$ are tradeables. All factors are nontradeable.

The price notation is summarize in table 1. We denote $p(z)_t^H$ the nominal price at time t of product z sold in country H and $p(z)_t^F$ the price of the same product sold in country F. Factor prices are denoted by $w(i)_t$. The exchange rate E_t as of time t is defined in units of

[5]The assumption of equal size is not important for our results. Like in Obstfeld and Rogoff (1995), percentage changes of endogenous variables (like the real exchange rate) depend on relative percentage changes of exogenous variables (like the money supply), but not on absolute changes conditioned by country size.

country H currency needed to buy one unit of country F currency.

2.1 Firms

Firms produce either a tradeable product sold in both countries or a nontradeable product available only at home. Tradeable producers z choose market-specific local currency prices $p(z)_t^H$, $p(z)_t^F$, and factor inputs $l(i,z)_t$, where $i \in \mathcal{H}$ for a producer in country H and $i \in \mathcal{F}$ for a firm located in country F. Nontradeable producers choose only a domestic market price. A production plan for a firm $z \in \mathcal{H}$ consists of a choice set $\mathcal{C}(z)$ of variables, where

$$\begin{aligned} z \in \mathcal{H}^T: &\qquad \mathcal{C}(z)_t = \left\{ p(z)_s^H, p(z)_s^F, l(i,z)_s, i \in \mathcal{H}, s \geq t \right\} \\ z \in \mathcal{H}^N: &\qquad \mathcal{C}(z)_t = \left\{ p(z)_s^H, l(i,z)_s, i \in \mathcal{H}, s \geq t \right\}. \end{aligned}$$

Firms have identical CES production functions with a substitution elasticity $\varphi > 1$. Let $D(t,t) = 1$ and $D(t,s) = \left[(1+R_t)(1+R_{t+1})\ldots(1+R_{s-1})\right]^{-1}$ denote the time t discount factor for period s under a sequence of nominal interest rates R_t. Under perfect foresight, the maximization problem for a firm $z \in \mathcal{H}$ becomes

$$V(z)_t = \max\nolimits_{\mathcal{C}(z)_t} \sum\nolimits_{s=t}^{\infty} D(t,s)\pi(z)_s \tag{1}$$

$$\begin{aligned} z \in \mathcal{H}^T: &\quad \pi(z)_t = p(z)_t^H y(z)_t^H + E p(z)_t^F y(z)_t^F - \int_{\mathcal{H}} l(i,z)_t w(i)_t^H \, di \\ z \in \mathcal{H}^N: &\quad \pi(z)_t = p(z)_t^H y(z)_t^H - \int_{\mathcal{H}} l(i,z)_t w(i)_t^H \, di \end{aligned} \tag{2}$$

$$\mathbf{y}(z)_t = \frac{1}{\alpha}\left[\alpha \int_{\mathcal{H}} l(i,z)_t^{\frac{\varphi-1}{\varphi}} \, di\right]^{\frac{\varphi}{\varphi-1}}. \tag{3}$$

The profit of tradeable producers in equation Eq. (2) consist of the domestic and foreign market revenue minus the production costs. Tradeable and nontradeable producers have the same production technologies to manufacture an output $\mathbf{y}(z)_t$. We choose a productivity parameter $\alpha = 2$ in Eq. (3) as a convenient normalization to obtain a production function $y = \frac{1}{2}l$ in the symmetric equilibrium. Firms in country F face an analogous choice problem.

2.2 Households

Households in the same country face the same consumption choices and have identical preferences. Their consumption preferences are summarized by a consumption index defined as

$$\begin{aligned} i \in \mathcal{H}: &\qquad \mathbf{c}(i)_t \equiv \left[\int_{\mathcal{H}\cup\mathcal{F}^T} c(i,z)_t^{\frac{\theta-1}{\theta}} \, dz\right]^{\frac{\theta}{\theta-1}} \\ i \in \mathcal{F}: &\qquad \mathbf{c}(i)_t \equiv \left[\int_{\mathcal{H}^T\cup\mathcal{F}} c(i,z)_t^{\frac{\theta-1}{\theta}} \, dz\right]^{\frac{\theta}{\theta-1}}, \end{aligned} \tag{4}$$

where $\theta > 1$. The parameter θ measures the elasticity of demand in the product market.[6] The consumption-based price indices for the two countries are given by[7]

$$\begin{aligned} P_t^H &\equiv \left[\int_{\mathcal{H}} \left[p(z)_t^H \right]^{1-\theta} dz + \int_{\mathcal{F}^T} \left[p(z)_t^H \right]^{1-\theta} dz \right]^{\frac{1}{1-\theta}} \\ P_t^F &\equiv \left[\int_{\mathcal{H}^T} \left[p(z)_t^F \right]^{1-\theta} dz + \int_{\mathcal{F}} \left[p(z)_t^F \right]^{1-\theta} dz \right]^{\frac{1}{1-\theta}}. \end{aligned} \tag{5}$$

There is an integrated world capital market in which all households can borrow and lend. However, the only asset traded is a real bond, denominated in units of the consumption index comprising all tradeable products. The bond price follows as

$$P_t^T \equiv \left[\int_{\mathcal{H}^T} \left[p(z)_t^H \right]^{1-\theta} dz + \int_{\mathcal{F}^T} \left[p(z)_t^H \right]^{1-\theta} dz \right]^{\frac{1}{1-\theta}}.$$

Let r_t denote the real interest rate earned on bonds between dates t and $t+1$, while $f_t(i)$ and $m_t(i)$ are the stock of bonds and domestic money held by a household entering date $t+1$. For a household $i \in \mathcal{H}$ with an aggregate factor supply $\mathbf{l}(i)_t = \int_{\mathcal{H}} l(i,z)dz$, we obtain a budget constraint

$$\begin{aligned} f(i)_t \frac{P_t^T}{P_t^H} + \frac{m(i)_t}{P_t^H} = [1 + r_{t-1}]\, f(i)_{t-1} \frac{P_t^T}{P_t^H} + \frac{m(i)_{t-1}}{P_t^H} - \mathbf{c}(i)_t + \\ + \frac{w(i)_t^H}{P_t^H} \mathbf{l}(i)_t + \frac{\pi(i)_t}{P_t^H} - \tau(i)_t. \end{aligned} \tag{6}$$

The budget constraint combines the real money demand $m(i)_t / P_t^H$, consumption $\mathbf{c}(i)_t$, real taxes $\tau(i)_t$ paid to the government, real factor income $w(i)_t^H \mathbf{l}(i)_t / P_t^H$, real capital income $\pi(i)_t / P_t^H$ from domestic equity and the return on bonds.

Households make consumption decisions $c(i,z)_t$, choose money balances $m(i)_t$ and set a factor price $w(i)_t$. A household plan for a household i consists of a set $\mathcal{C}(i)$ of choice variables, where

$$\begin{aligned} i \in \mathcal{H}: \quad & \mathcal{C}(i)_t = \left\{ w(i)_s^H, m(i)_s, c(i,z)_s, z \in \mathcal{H} \cup \mathcal{F}^T, s \geq t \right\} \\ i \in \mathcal{F}: \quad & \mathcal{C}(i)_t = \left\{ w(i)_s^F, m(i)_s, c(i,z)_s, z \in \mathcal{H}^T \cup \mathcal{F}, s \geq t \right\}. \end{aligned}$$

Household preferences are defined over the consumption index $\mathbf{c}(i)_t$, real money balances and the effort expended to provide the factor. Households derive utility only from domestic

[6] In our model, the traded and nontraded sector do not differ in the degree of competition. For a model with a competitive traded sector and a monopolistic nontraded sector, see Lane (1997).

[7] The price index is defined as the minimal expenditure needed to purchase a unit of consumption $\mathbf{c}(i)_t$. Formally, P_t^H is a function of individual product prices $p(z)_t$ such that

$$P_t^H \mathbf{c}(i)_t = \min_{c(i,z)_t} \int_{\mathcal{H} \cup \mathcal{F}^T} p(z)_t c(i,z)_t dz \quad \text{s.t.} \quad \mathbf{c}(i)_t = 1.$$

currency, not from foreign currency. For a household $i \in \mathcal{H}$ with perfect foresight, the utility maximization problem can be stated as

$$U(i)_t = \max_{\mathcal{C}(i)_t} \sum\nolimits_{s=t}^{\infty} \beta^{s-t} \left[\log \mathbf{c}(i)_t + \chi \log \left[\frac{m(i)_t}{P_t^H} \right] - \frac{\kappa}{2} \mathbf{l}(i)_t^2 \right], \tag{7}$$

subject to the budget constraint Eq. (6). In equation Eq. (7), $1 > \beta > 0$, $\varepsilon > 0$ and $\kappa > 0$. A reciprocal maximization problem holds for a household in country F, whose real money balances are given by $m(i)_t / P_t^F$.

2.3 Ownership Structure and Taxation

Firms hold market power and make monoplistic profits. We therefore have to define an ownership structure. For simplicity, we assume a symmetric ownership structure in which each household owns an equal share of all domestic firms, resulting in a capital income $\pi(i)_t$,[8]

$$\begin{aligned} i \in \mathcal{H}: \quad & \tfrac{1}{2}\pi(i)_t \equiv \int_{\mathcal{H}} \pi(z)_t dz \\ i \in \mathcal{F}: \quad & \tfrac{1}{2}\pi(i)_t \equiv \int_{\mathcal{F}} \pi(z)_t dz. \end{aligned}$$

Furthermore, we assume that government spending is zero and the government budget balanced. For an aggregate money supply $\frac{1}{2}M_t^H$ in country H,[9] and a household tax $\tau(i)_t$, the government budget constraint simplifies to

$$\int_{\mathcal{H}} \tau(i)_t di + \frac{\frac{1}{2}M_t^H - \frac{1}{2}M_{t-1}^H}{P_t^H} = 0, \tag{8}$$

where the second term denotes the seignorage income of the government.[10]

3 The Model Solution

The following section summarizes the solution to the model in four propositions. The intermediate steps are provided in the appendix. We only emphasize the solution method and interpret the results.

[8]The empirical evidence suggests that international capital diversification is relatively small. Most capital is owned by domestic residents. Complete ownership of domestic assets by domestic residence is an approximation to the home equity bias.

[9]An aggregate variable X is defined in *per capita* terms; that is, $\frac{1}{2}X^H \equiv \int_{\mathcal{H}} x(i)di$.

[10]The analysis can be extended to fiscal policies without a balanced budget. For such an extension, see Obstfeld and Rogoff (1995).

3.1 First-Order Conditions

Utility and profit maximization yields 5 first-order conditions for each of the two countries: the consumption demand for domestic and foreign products Eqs. (26),(27), the Euler condition Eq. (28), the money demand Eq. (29), the factor demand Eq. (30), the domestic and foreign product pricing conditions Eqs. (31),(32) and the factor pricing condition Eq. (33). These conditions are stated in appendix A. The monopolistic market structure implies a product price mark-up of $\theta/\theta-1$ over the factor price over production costs and a factor price mark-up of $\varphi/\varphi-1$ over the marginal disutility of labor. Given identical demand elasticities in the domestic and foreign market, price mark-up over domestic factor costs have to be identical for domestic and export products.

3.2 Symmetric Equilibrium

The symmetric model setup with identical production technologies, identical household preferences and symmetric ownership distribution allows us to restrict attention to the symmetric equilibrium with identical household and firm behavior within a country. Aggregate variables (expressed in *per capita* terms) are capitalized and steady state values of the symmetric equilibrium are marked by overbars; that is $x(i)=\overline{X}$. The total aggregate output per household $\mathbf{Y}^H$ is distinguished by bold print.[11] A closed form solution for the symmetric steady state exists for the special case of zero net foreign assets. Following Rogoff and Obstfeld (1995), we denote this particular steady state by zero subscripts. The solution is provided in proposition 1 and the derivation in appendix B.

Proposition 1 (Symmetric Equilibrium) *For two identical open economies $j=H,F$ (defined by equations 1 to 8) with a nontradeable share 2η and zero net foreign assets, $\overline{F}_0^j=0$, the steady state levels of aggregate output $\overline{\mathbf{Y}}_0^j$, consumption $\overline{C}_0^j$, factor supply $\overline{L}_0^j$, price level $\overline{P}_0^j$, and the nominal exchange rate $\overline{E}_0$ are given by*

$$\overline{\mathbf{Y}}_0^j = (1-\eta)\overline{C}_0^j = \overline{L}_0^j = \left[\frac{(\varphi-1)(\theta-1)}{\varphi\theta\kappa}\right]^{\frac{1}{2}} \tag{9}$$

$$\overline{P}_0^j = \frac{\overline{p}_0{}^j}{(1-\eta)^{\frac{1}{\theta-1}}} = \left[\frac{(1-\beta)}{(1-\eta)^{\frac{1}{\theta-1}}\chi\overline{\mathbf{Y}}_0^j}\right]^{\frac{1}{2}}\overline{M}_0^j \tag{10}$$

$$\overline{E}_0 = \frac{\overline{M}_0^H}{\overline{M}_0^F}, \tag{11}$$

[11]The aggregate output in per capita terms is defined as the sum of tradeable and nontradeable output

$$\frac{1}{2}\overline{\mathbf{Y}}^H \equiv \int_{\mathcal{H}} \mathbf{y}(z)dz = \left(\frac{1}{2}-\eta\right)\overline{Y}_T^H + \eta\overline{Y}_N^H.$$

where $\theta > 1$ and $\varphi > 1$.

The aggregate output level is influenced by the elasticity of substitution in the product and factor market. Higher substitutability in either market (φ, θ larger) enhances the output as lower price mark-ups increases the product and factor demand. Aggregate output does not depend on the percentage 2η of tradeables since we assume identical demand elasticities for tradeables and nontradeables and the same production technology for both sectors. Household utility and the consumption index $\overline{\mathbf{c}}(i) = (1-\eta)^{\frac{1}{\theta-1}}\overline{\mathbf{Y}}_0$ increases in the percentage of tradeables. The symmetric equilibrium for monopolistic factor and product markets derived here corresponds to a similar result obtained by Blanchard and Kiyotaki (1987) in a static closed economy framework.

3.3 Log-Linearized Model for Factor Price Rigidities

This section log-linearizes the model around the symmetric steady state characterized in section 3.2. We assume short-run nominal factor prices (wages) rigidities, which can be explained by institutional features of the labor market.[12] Product prices are flexible for both the domestic and foreign market.

Since the nominal rigidities are transitory a linear approximation of the first-order condition has to distinguish between the short-run adjustment to shocks and policy changes and the long-run dynamics based on factor price flexibility. Three examples of log-linearizations are provided in appendix C. Similar to Obstfeld and Rogoff (1995), we denote short-run deviations from the steady state by hats; thus for any variable, $\widehat{X} \equiv dX/X_0$. By contrast, long-run deviations from the benchmark value $\overline{X}_0$ are denote by $\widehat{\overline{X}} \equiv d\overline{X}/\overline{X}_0$. To further simplify notation, we represent country differences in any variable by $\Delta X \equiv X^H - X^F$. Proposition 2 summarizes the dynamics around the symmetric steady state.

Proposition 2 (Log-linearized Model) *Assume two identical open economies $j = H, F$ with nontradeables shares 2η experience relative money supply shocks $\Delta\widehat{M}, \Delta\widehat{\overline{M}}$ and aggregate supply shocks $\Delta\widehat{\kappa}, \Delta\widehat{\overline{\kappa}}$ in the short and long run, respectively. For the country differences $\Delta X \equiv X^H - X^F$ of an aggregate variable X^j, short-run factor price (wage) rigidities yield a short-run dynamics*

$$\Delta\widehat{P} = \frac{1-2\eta}{1-\eta}\widehat{E} \tag{12}$$

[12] Wage rigidities have been rationalized as implicit contracts (Azariadis and Stiglitz 1983, Rosen 1985), by efficiency wage models (Yellen 1984, Stiglitz 1986) or insider-outsider models (Lindberg and Snower 1987). For a survey, see Haley (1990).

$$
\begin{aligned}
\Delta\widehat{\mathbf{Y}}^d &= \frac{\theta}{1-\eta}\frac{1-2\eta}{1-\eta}\widehat{E} + \frac{\eta}{1-\eta}\Delta\widehat{C} &(13)\\
\Delta\widehat{L} &= \Delta\widehat{\mathbf{Y}} &(14)\\
\Delta\widehat{M} - \Delta\widehat{P} &= \Delta\widehat{C} - \frac{\beta}{(1-\beta)}\left(\widehat{\widehat{E}} - \widehat{E}\right), &(15)
\end{aligned}
$$

their long-run dynamics follows as

$$
\begin{aligned}
\Delta\widehat{\widehat{P}} &\equiv \frac{1-2\eta}{1-\eta}\widehat{\widehat{E}} + \frac{\eta}{1-\eta}\Delta\widehat{\widehat{W}} &(16)\\
\Delta\widehat{\widehat{\mathbf{Y}}}^d &= \frac{\theta}{1-\eta}\frac{1-2\eta}{1-\eta}\widehat{\widehat{E}} + \frac{\eta}{1-\eta}\Delta\widehat{\widehat{C}} - \theta\frac{1-2\eta}{(1-\eta)^2}\Delta\widehat{\widehat{W}} &(17)\\
\Delta\widehat{\widehat{L}} &= \Delta\widehat{\widehat{\mathbf{Y}}} &(18)\\
\Delta\widehat{\widehat{M}} - \Delta\widehat{\widehat{P}} &= \Delta\widehat{\widehat{C}} &(19)\\
\Delta\widehat{\widehat{W}} &= \Delta\widehat{\widehat{L}} + \Delta\widehat{\widehat{P}} + \Delta\widehat{\widehat{C}} + \Delta\widehat{\widehat{\kappa}}, &(20)
\end{aligned}
$$

and the intertemporal constraints are

$$
\begin{aligned}
\Delta\widehat{C} &= \Delta\widehat{\widehat{C}} + \left(\widehat{E} - \Delta\widehat{P}\right) - \left(\widehat{\widehat{E}} - \Delta\widehat{\widehat{P}}\right) &(21)\\
\Delta\widehat{\widehat{C}} &= \Delta\widehat{\widehat{L}} + \Delta\widehat{\widehat{W}} - \Delta\widehat{\widehat{P}} + \overline{r}\frac{2d\overline{F}_0^H\overline{P}_0^T}{\overline{\mathbf{Y}}_0\overline{p}_0^H} &(22)\\
\frac{2d\overline{F}_0^H\overline{P}_0^T}{\overline{\mathbf{Y}}_0\overline{p}_0^H} &= \Delta\widehat{L} - \Delta\widehat{P} - \Delta\widehat{C}. &(23)
\end{aligned}
$$

Eq. (12) relates the nominal exchange rate change $\widehat{E}$ to the relative change of the price level $\Delta\widehat{P}$ in the two countries. Fewer tradeables imply that a nominal exchange rate change has a smaller impact on the relative price level. In order to obtain any given relative price adjustment, we need a larger exchange rate change as the percentage of nontradeables increases. Nontradeables thus create an *exchange rate magnification effect* by untying the relative price change from the exchange rate change. This effect generates short-run PPP deviations. The relative product demand in Eq. (13) is linked only to the exchange rate in the case of only tradeables ($\eta = 0$), but becomes closely tied to the relative consumption change $\Delta\widehat{C}$ as the percentage of nontradeables increases. This is intuitive as more nontradeables tend create a *home product consumption bias.* Eqs. (16) states the long-run relative price change which accounts for a change in the relative factor price $\Delta\widehat{\widehat{W}}$. In the long run relative price changes can be induced by relative factor price changes as we consider less open economies. Nontradeables can therefore produce a *Balassa-Samulson* effect across countries with different factor price changes. In the absence of technological change, relative output changes are proportional to relative factor input changes as expressed by Eqs. (14) and (18). Eqs. (15) and (19) characterize the relative short-run and long-run money demand, respectively. The change in the relative real money demand is proportional to the relative consumption change. An expected exchange rate depreciation $\widehat{\widehat{E}} - \widehat{E}$ decreases the short-run relative money demand. Eq. (20) characterizes optimal long-run factor price setting. We allow for a permanent relative factor supply shock $\Delta\widehat{\widehat{\kappa}}$ (percentage change in utility parameter κ). The Euler condition is stated in Eq. (21). Notice that short-run and long-run relative consumption changes differ by the of the short-run PPP deviation relative to the long-run PPP deviation. A depreciating real exchange rate implies a differential real return on net foreign assets and therefore a relative incentive for the home country to dissave. This *differential real return effect* depends on PPP deviations and is therefore related to the percentage of nontradeables. Eq. (23) relates the change of current account surplus $d\overline{F}_0^H \overline{P}_0^T$ (expressed relative to the value of aggregate output $\overline{\mathbf{Y}}_0 \overline{p}_0^H$) to the relative changes in the factor inputs, price levels and consumption. Eq. (22) expresses the long-run budget constraint. Long-run relative consumption changes $\Delta\widehat{\widehat{C}}$ can be financed by relative changes in factor inputs $\Delta\widehat{\widehat{L}}$, real wages $\Delta\widehat{\widehat{W}} - \Delta\widehat{\widehat{P}}$ or capital income from net foreign assets $\overline{r} 2d\overline{F}_0^H \overline{P}_0^T / \overline{\mathbf{Y}}_0 \overline{p}_0^H$.

Altogether, we have twelve conditions for a total of twelve endogenous variables: $\Delta\widehat{Y}$, $\Delta\widehat{L}$, $\Delta\widehat{C}$, $\widehat{E}$, $\Delta\widehat{P}$, $\Delta\widehat{\widehat{Y}}$, $\Delta\widehat{\widehat{L}}$, $\Delta\widehat{\widehat{C}}$, $\widehat{\widehat{E}}$, $\Delta\widehat{\widehat{P}}$, $\Delta\widehat{\widehat{W}}$ and $2d\overline{F}_0^H \overline{P}_0^T / \overline{\mathbf{Y}}_0 \overline{p}_0^H$. This allows us to solve the model for any given shock to the exogenous variables.

3.4 Permanent Money and Aggregate Supply Shocks

The following section solves the log-linear model for a one-time unanticipated change in the relative money supply and labor supply. We assume that the changes the money and labor supply are permanent, that is[13]

$$\Delta\widehat{M} = \Delta\widehat{\widehat{M}} \tag{24}$$

$$\Delta\widehat{\kappa} = \Delta\widehat{\widehat{\kappa}} > 0. \tag{25}$$

A positive term $\Delta\widehat{\widehat{\kappa}} > 0$ corresponds to relative factor supply decrease in the home country. Given twelve log-linearized equilibrium conditions for twelve endogenous variables, solving the model is a straightforward exercise. Proposition 3 summarizes the results:

Proposition 3 (Exchange Rate Dynamics) *Assume two identical open econ-omies with a nontradeable share 2η. Permanent relative money shocks $\Delta\widehat{M}$ and aggregate supply shocks $\Delta\widehat{\widehat{\kappa}}$ result in changes in the relative price index $\Delta\widehat{P}$, the nominal exchange rate $\widehat{E}$, and the*

[13]Permanent money shocks are assumed in the classical Dornbusch (1976) exercise. But transitory shocks to either money supply or productivity can be analyzed in a similar way.

real exchange rate $\widehat{E}-\Delta\widehat{P}$ *given by*

$$\begin{aligned}\Delta\widehat{P} &= k_1(\eta,\theta)\Delta\widehat{M}+k_2(\eta,\theta)\Delta\widehat{\kappa}\\ \widehat{E} &= \frac{1-\eta}{1-2\eta}\Delta\widehat{P}\\ \widehat{E}-\Delta\widehat{P} &= \frac{\eta}{1-2\eta}\Delta\widehat{P}\end{aligned}$$

respectively. The functions $k_1(\eta,\theta)>0$ *and* $k_2(\eta,\theta)>0$ *are stated in the appendix D.*

Our discusion of proposition 3 focuses on the real exchange rate change $\widehat{E}-\Delta\widehat{P}$. Figure 1 presents the real exchange rate depreciation for a one percent relative money supply shock as a function of the share of tradeables $1-2\eta$. The percentage change in the real exchange rate decreases in openness of the economies. A relative money supply shock produces a new money market equilibrium by a combination of relative consumption increase and relative price level adjustment. A more closed economy requires a larger nominal exchange rate change to produce the same relative price level change. For any relative consumption change, the more closed economy will be characterized by a larger exchange rate change. This is the *exchange rate magnification* effect of nontradeables. Two forces counteract this effect. First, more nontradeables create a *home product consumption bias.* The asymmetric money supply shock therefore translates into a more asymmetric consumption expansion and reduces the need for a short-run relative price level adjustment. This tends to decrease the exchange rate magnification effect. Second, the real exchange rate devaluation of a monetary shock is temporary. This creates a predictable real return differential for net foreign assets between home and foreign households. This *differential real return effect* re-enforces the relative consumption changes, which again tend to balance the money market and require a smaller exchange rate change. We can show that the exchange rate magnification effect dominates the two other effects (appendix D).

Figure 2 shows the exchange rate depreciation for a negative relative factor supply shock ($\Delta\widehat{\kappa}>0$). The lower home factor supply translates into a relative output and consumption decrease. The relative consumption decrease requires a relative price adjustment if the relative money supply is constant. The *exchange rate magnification effect* implies that the nominal exchange rate change compensates the decreasing impact of export prices on the price indices as we consider a more closed economy. The *home product consumption bias* now tends to re-enforce the exchange rate magnification effect as it increases relative consumption changes and the required relative price adjustment which balances the money market. The negative factor supply shock again produces a real exchange rate depreciation which is decreasing in economic openness.

The solution of the model was undertaken in a nonstochastic setting with a single unanticipated shock. Repeated supply and monetary shocks will generate current account changes which may move us away from the symmetric steady state. However, our analysis concerning the role of nontradeables carries over to the stochastic case.[14] If we consider a dynamic setting with repeated (iid) money and factor supply shocks, a larger real exchange rate effect translates into a larger volatility measure. This justifies the following proposition:

Proposition 4 (Volatility Implications) *Independent money and factor supply shocks imply (ceteris paribus) an inverse relationship between openness and real exchange rate volatility.*

4 Evidence on the Volatility-Openness Linkage

In this section we use cross country data to test the model implication that the real exchange rate volatility is inversely related to the openness of an economy. We first need to define a suitable measure of real exchange rate volatility. Previous studies have often focused on the bilateral dollar exchange rates. However, any specific bilateral real exchange rate might not be representative of the trade flows of some countries. We therefore choose to aggregate different bilateral real exchange rates in one trade-weighted effective real exchange rate. A second choice concerns the frequency at which we measure real exchange rate changes. Since monetary models tend to perform better at low frequencies, we measure real exchange rate changes over 3 year periods.[15] Also, low frequency movements cannot easily be hedged in derivative markets and therefore pose the greatest policy concern.

More precisely, we measure real exchange rate volatility V as the standard deviation for the percentage changes of the real effective exchange rate RE over intervals of 36 months.[16] Thus, for monthly data of country i we define

$$V_i = \left[\frac{1}{T} \sum_t \left(\frac{RE_{t+36,i} - RE_{t,i}}{RE_{t,i}} \right)^2 \right]^{\frac{1}{2}}.$$

The theoretical model suggests a concave relationship between volatility and openness. To capture this non-linearity, we introduce the inverse of the import share, $[\text{Imports/GDP}]^{-1}$,

[14]For an explicitly stochastic setup with nontradeables the reader is refered to Obstfeld and Rogoff (1999).

[15]Mark (1996) and Mark and Choi (1997) report for example that monetary models outperform the random walk hypothesis in out-of-sample tests only for low frequency movements above 12 months.

[16]We also examined higher frequency measures of 1 month, 3 months and 12 months. The results are similar for the 12 months period, although less significant. No evidence for a volatility-openness linkage emerges using high frequency volatility measures of 1 month or 3 months.

as the independent variable.[17] A simple cross-sectional regression can be formulates as

$$V_i = \alpha_0 + \alpha_1 \ [\text{Imports/GDP}]_i^{-1} + \alpha_2 Z_i + u_i.$$

The variables Z_i represent different control variables. The model developed in the previous section implies that the coefficient α_1 is positive.

4.1 Data

The analysis is based on a cross-country data set constructed by Romer (1993). Romer's original sample consists of 114 countries.[18] For the measures of real exchange rate volatility we used IMF data on effective real exchange rates (IMF code: xxx..RECZF...). The tradeweighted effective real exchange rates use consumption based price indices and correspond to our theoretical measure. In order to obtain a reliable estimate of real effective exchange rate volatility we only considered those countries for which real effective exchange rate is reported at least since 1980. This leaves us with 56 countries in the Romer sample.[19] The sample includes a subset of 21 OECD countries.[20] The data on import share is the same as used by Romer (1993) and Lane (1997). The Rome data also privides a set of useful control variables. These include the per capita income in 1980 measured in US dollars, average inflation, the average number of revolutions and coups as a measure of political stability (Barro (1991)), as well a measures of central bank independence (Cukierman et al. (1992)). Finally, I add a set of dummy variable for those countries which have exchange rate commitments in 1995 according to the International Financial Statistics (IMF, 1996).[21]

Figure 3 presents a scatterplot of volatility against the degree of openness for the full sample. Volatility outliers are Nigeria and Uganda. Two countries with extremely high openness are Bahrain and Malta. Figure 4 shows a separate scatterplot for the 21 OECD countries. Average volatility in the OECD countries is 0.0439 compared to 0.0853 in the full sumple. Developing countries are on average characterized by much higher real exchange rate

[17] Alternatively, we could introduced polynomials of the import share to capture the nonlinear linkage between volatility and openness. This introduces, however, additional degrees of freedom. We chose the more parsimonious regression specification.

[18] It includes all noncentrally planned economies listed by Summers and Heston (1991), but excludes seven noncentrally planned economies for insufficient data. They are Afghanistan, Angola, Chad, Guinea, Iraq, Mali, and Mozambique.

[19] Excluded are also two countries without independent currencies, namely Luxenburg and Guyana.

[20] The OECD countries without effective real exchange rate data are Australia, Greece and Turkey.

[21] OECD countries with exchange rate commitments are Austria, Belgium, Denmark, France, Germany, Ireland, Netherlands, Portugal, Spain.

volatility. The following analysis reports results for the full sample and the OECD subsample separately.

4.2 Basic Results

Table 2 shows the regression results for the full sample of 54 countries. Column (1) reports the specification without any controls. The correlation between volatility and the inverse of the import share is significant on a 1 percent level with an adjusted $\overline{R}^2$ of 0.164. Inclusion of the (log) per capita GDP in column (2) considerably improves the fit of the regression. Controling for per capita income increases the adjusted $\overline{R}^2$ to 0.414, while the coefficient for (the inverse of) the import share remains highly significant. Per capita GDP represents an important control for a data set which combines countries of various developpment level. Developing counties are plausibly exposed to larger real and monetary shocks than developed counties. Explanations range from their higher dependence on volatile world commodity prices to larger monetary shock as consequence of political instability. Column (3) includes average inflation for the period 1973-1992 and the number of revolutions and coups as measures of political stability. Both measures are positively related to volatility on a 5 and 10 percent level, respectively. The coefficient on the openness measure decreases, but remains significant on a 5 percent level. In column (4) we test if the openness-volatility linkage is robust to a control for the exchange rate regimes. A dummy variable is used to distinguish all countries for which the IMF lists exchange rate commitments. The openness variable remains significant on a 5 percent level.

As developping countries introduce considerable heterogeneity into our sample, we repeat these regressions for the subsample of 21 OECD countries. The ceteris paribus condition in Proposition 4 (requiring real and monetary shocks of similar magnitude) is plausibly better fulfilled for the OECD subsample. The results are shown in Table 3. The basic regression (without controls) reported in column (1) now shows a surprisingly high adjusted $\overline{R}^2$ of 0.470. Approximately half of the cross-sectional volatility is therefore explained by economic openness. Inclusion of the log per capita GDP in column (2) improves the fit only slightly. Columns (3) and (4) consider an index of central bank independence and a dummy for exchange rate commitment as additional controls. Both measures are negatively correlated with volatility and significant. In both cases the coefficient of the openness measure decreases only slightly and remains highly significant at a 1 percent level. The OECD sample identifies openness as the most important determinant of real exchange rate volatility for developped countries.

5 Alternative Explanations

5.1 Endogenous Openness

The theoretical framework and the econometric approach in the previous section consider openness as an exogenous variable. However, exchange rate risk may have a feed-back effect on trade integration itself. This risk-trade channel is particularly plausible for low frequency movements of the real exchange rate for which hedging strategies are either unavailable or very costly. A large empirical literature is devoted to this issue with contradictory results.[22]

Our cross-sectional data allow us to address the issue of trade endogeneity with an instrumental variable approach. We simply reestimate the basic regression treating openness as endogenous and using (the log of) a of country's land area (relative to the sample average) as instrument. The land area can reasonably be assumed to be exogenous and not determined by exchange rate risk. At the same time our measure of a country's (relative) land area is correlated with (the inverse of) the import share. For the full sample the correlation is only -0.544. Land area is a better instrument for the OECD sample with correlation of -0.718.

Table 4 shows the instrumental variable estimates. Column (1) reports results corresponding the same controls as column (2) in table 2. The coefficient on openness increase slightly, but the standard error is almost twice as high. A high coefficient is evidence against the risk-trade channel. If trade is endogenously depressed by exchange rate risk the IV estimates should be lower than the OLS estimate. The larger standard error results from the noisy instrument. It is therefore preferable to focus on the OECD sample for which instrument quality is higher. Comparing column (3) in table 4 to column (2) in table 3 we find a higher coefficient for the instrumental variable estimate on openness. The same increase of the IV estimate relative to the OLS estimate is obtained if we control for exchange rate commitments in column (4). We conclude that the openness-volatility linkage is not induced by a trade-risk channel.

[22] Studies by Hooper and Kohlhagen (1978), Gotur (1985), Bailey, Tavlas and Ulan (1987), and Asseery and Peel (1991), among others, do *not* find support for the trade depressing effect of volatility. On the other hand, Cushman (1983, 1986, 1988), Akhtar and Hilton (1984), Kenen and Rodrik (1986), Thursby and Thursby (1987), De Grauwe (1988), Peree and Steinherr (1989), Koray and Lastrapes (1989) and Arize (1995,1996) claim the opposite result.

5.2 Deviations from the Law of one Price

Deviations from the law of one price (LOP) are a well documented for short time horizons. Furthermore, LOP deviations become more important with geographic distance (Engel and Roger, 1996). But since our measure of openness is strongly correlated with land area, the volatility-openness linkage may simply capture deviations from the LOP. A neccessary condition for this explanation is that LOP deviations are persistent. On the other hand we expect LOP deviations for traded goods to be at least as pronounced in the very short run. The LOP deviations should also be detectable at high frequency measures of volatility.

Table 5 shows the standard regression for the OECD sample with volatility measured at frequencies of 1 month, 3 months, 12 months and 36 months. A openness measure is significant only at low frequencies of 12 and 36 months. No linkage between real exchange rate volatility and openness exists at the monthly frequency. However, LOP deviations based on geographic distance should be relevant at any frequency measure. While this evidence does in no way imply the absense of LOP deviations, it disqualifies them as an explanation for the observed volatility-openness linkage.[23]

5.3 Openness and the Intensity of Shocks

A third explanation for the volatility-openness linkage might be that more open economies do not experience real and monetary shocks of the same intensity as do closed economies. More open economies might for example adopt institutions and policies which reduce the intensity of relative shocks. If this is the case we can explain the observed relationship without the exchange rate magnification effect of nontradeables.

The literature distinguishes sterilized policies without relative price impact from non-sterilized policies, which change the relative inflation rate. Sterilized intervention have often been judged as largely ineffective.[24] Empirically, their impact seems to be small and difficult to detect (Edison, 1993). Real exchange rate effects over a period of 3 years appears even more questionable. Our analysis therefore focuses on non-sterilized policies which stabalize the relative price level. If more open economies engage in (non-sterilized) real exchange rate

[23] A possible extension of our model would be to assume that a certain percentage of the tradeable products have sticky nominal prices in term of the foreign currency (Betts and Devereux, 1995). This results in an increased level of exchange rate volatility without changing the qualitative linkage between the exchange rate effect and openness for any given shock.

[24] According to Obstfeld and Rogoff (1995, JEP, p. 76) "steralized intervention operations are largely smoke and mirrors. Because they do not change the relative money supplies, steralized interventions can have only modest effects, if any, on interest and exchange rates."

smoothing, we should expect their inflation rate to follow more closely those of their main trading partners. Such convergence of inflation rates has for example been observed within the European monetary system. Inflation convergence can be measured directly by looking at the standard deviation of the relative price level over 3 year periods.[25] If non-sterilized policies smooth real exchange rates for open economies we should see a negative correlation between relative price volatility and openness.[26]

Figure 5 plots the standard deviation of the relative price change for 20 OECD countries. The correlation between this volatility measure and openness is positive, but insignificant as shown in table 6, column (1). Controlling for per capita income, central bank independence and exchange rate regime choice does not indicate a strong negative correlation either. We conclude that the volatility-openness linkage for the real exchange rate is not induced by a similar volatility pattern of the relative prices as should be the case if relative shocks are smaller in more open economies.

6 Conclusion

This paper examines the role of nontradeables for the volatility of the real exchange rate. Monetary theory suggest that real exchange rate volatility is inversely related to economic openness. Nontradeables require large exchange rate changes so that the exchange rate pass-through of tradeable prices can contribute to the short-run money market equilibrium after a money supply shock. We call this the *exchange rate magnification effect* of nontradeables.

The empirical evidence on a cross-section of 54 countries (and particular the OECD sub-sample) is supportive of the conjectured openness-volatility linkage. The inverse relationship between volatility and openness is robust to the inclusion of various control measures. We also discard an endogenous risk-trade channel, distance related LOP deviations or a systematic concentration of relative shocks in closed economies as alternative explanations for the observed relationship. Our results predict large real exchange rate volatility for the future Euro/Dollar rate or the Euro/Yen rate if the level of intercontinental trade remain on its presently modest level.

[25] We calculate the relative (consumer) price level, $\Delta P = P^H - P^F$, using trade weights of the home country with the OECD trading partner for the construction of P^F. The volatility of the relative price level is calculated as before as the standard deviation of the percentage changes $\Delta\widehat{P}$.

[26] In the absense of stablizing policies we expect a positive correlation. Note that proposition 3 relates unanticipated shocks to the relative price level. The coefficients $k_1(\eta, \theta)$ and $k_2(\eta, \theta)$ are increasing in economic openness. This is intuitive as short-run relative price changes are transmitted through import price changes, which enter more extensively into the price index of a more open economy.

Appendix A: First-Order Conditions

Utility maximization implies the optimal consumption demand Eqs. (26),(27), the Euler condition Eq. (28) and the optimal money demand Eq. (29) for a nominal interest rate in country H defined by $(1+R_t^H) \equiv (1+r_t)P_{t+1}^H/P_t^H$. For an exporting firm we denote the value of one unit of output as the maximum of domestic and foreign unit revenue; that is $q(z)_t^H \equiv \max\left[p(z)_t^H, E_t p(z)_t^F\right]$. Cost minimization requires factor inputs according to Eq. (30). Finally, the first-order conditions for the product prices Eqs. (31),(32) and the factor prices Eq. (33) follow from monopolistic price setting for the given consumer and labor demand functions. Similar relationships are obtained for country F.

$$i \in \mathcal{H},\, z \in \mathcal{H}: \quad c(i,z)_t = \left[\frac{p(z)_t^H}{P_t^H}\right]^{-\theta} \mathbf{c}(i)_t \tag{26}$$

$$i \in \mathcal{H},\, z \in \mathcal{F}^T: \quad c(i,z)_t = \left[\frac{p(z)_t^F}{P_t^H}\right]^{-\theta} \mathbf{c}(i)_t \tag{27}$$

$$i \in \mathcal{H}: \quad \mathbf{c}_{t+1}(i)\frac{P_{t+1}^H}{P_{t+1}^T} = \beta(1+r_t)\mathbf{c}_t(i)\frac{P_t^H}{P_t^T} \tag{28}$$

$$i \in \mathcal{H}: \quad \frac{m(i)_t}{P_t^H} = \chi \mathbf{c}(i)_t \frac{(1+r_t)P_{t+1}^T}{(1+r_t)P_{t+1}^T - P_t^T} \tag{29}$$

$$i \in \mathcal{H},\, z \in \mathcal{H}: \quad l(i,z)_t = \left[\frac{w(i)_t^H}{q(z)_t^H}\right]^{-\varphi} 2\mathbf{y}(z)_t \tag{30}$$

$$z \in \mathcal{H}^N: \quad \frac{\theta}{\theta-1}W_t^H = p(z)_t^H \tag{31}$$

$$z \in \mathcal{H}^T: \quad \frac{\theta}{\theta-1}W_t^H = p(z)_t^H = E_t p(z)_t^F \tag{32}$$

$$i \in \mathcal{H}: \quad \frac{w(i)_t^H}{\mathbf{c}(i)_t P_t^H} = \frac{\varphi}{\varphi-1}\kappa \mathbf{l}(i)_t \tag{33}$$

Appendix B: Symmetric Equilibrium

For a constant consumption in steady state, the real interest rate is tied down by the consumption Euler condition Eq. (28) as $\overline{r} = (1-\beta)/\beta$. The total aggregate output per household $\mathbf{Y}^H$ is distinguished by bold print and defined as the sum of the output of tradeable and nontradeable producers

$$\frac{1}{2}\overline{\mathbf{Y}}^H \equiv \int_{\mathcal{H}} \mathbf{y}(z)dz = \left(\frac{1}{2}-\eta\right)\overline{Y}_T^H + \eta \overline{Y}_N^H.$$

Under a symmetric ownership structure, the average capital income of a household follows as $(j = H, F)$

$$\overline{\Pi}^j = \frac{1}{\theta-1}\overline{W}^j\overline{\mathbf{Y}}^j = \frac{1}{\theta}\overline{p}^j\overline{\mathbf{Y}}^j$$

and the household budget constraint implies

$$\overline{P}^j \overline{\mathbf{c}}^j = \overline{W}^j \overline{L}^j + \overline{\Pi}^j + \overline{r}\,\overline{F}^j \overline{P}^T = \overline{p}^j \overline{\mathbf{Y}}^j + \overline{r}\,\overline{F}^j \overline{P}^T. \tag{34}$$

A closed form solution for the symmetric steady state exists for the special case of zero net foreign assets where $\overline{F}_0^H = \overline{F}_0^F = 0$. Combining Eqs. (31)-(34) implies

$$\frac{\theta - 1}{\theta} = \frac{\overline{W}_0^j}{\overline{p}_0^j} = \frac{\varphi}{\varphi - 1} \kappa \overline{L}_0 \frac{\overline{P}_0^j \overline{\mathbf{c}}_0^j}{\overline{p}_0^j} = \frac{\varphi}{(\varphi - 1)} \kappa \overline{L}_0 \overline{\mathbf{Y}}_0^j = \frac{\varphi}{(\varphi - 1)} \kappa \left[\overline{\mathbf{Y}}_0^j \right]^2.$$

Thus we obtain the steady state output in proposition 1.

Appendix C: Log-Linearizations

It is straightforward to derive the log-linear relationships in proposition 3 from the first-order conditions Eqs. (26)-(33). We have to distinguish the short-run case with constant wage from the long-run situation of wage flexibility. For example, the first-order conditions for the price imply Eqs. (35)-(38) and the difference of the aggregate price levels Eqs. (39) and (40) add to a relative price change Eq. (41). Accounting for wage flexibility in the long-run we obtain the corresponding long-run Eqs. (42)-(46).

$$z \in \mathcal{H}^N : \quad \widehat{p}(z)^H = 0 \tag{35}$$

$$z \in \mathcal{H}^T : \quad \widehat{p}(z)^H = 0 \quad \wedge \quad \widehat{p}(z)^F = -\widehat{E} \tag{36}$$

$$z \in \mathcal{F}^T : \quad \widehat{p}(z)^F = 0 \quad \wedge \quad \widehat{p}(z)^H = \widehat{E} \tag{37}$$

$$z \in \mathcal{F}^N : \quad \widehat{p}(z)^F = 0 \tag{38}$$

$$(1-\eta)\widehat{P}^A = \eta \widehat{p}(\mathcal{H}^N)^H + \left(\tfrac{1}{2} - \eta\right) \widehat{p}(\mathcal{H}^T)^H + \left(\tfrac{1}{2} - \eta\right) \widehat{p}(\mathcal{F}^T)^H \tag{39}$$

$$(1-\eta)\widehat{P}^B = \left(\tfrac{1}{2} - \eta\right) \widehat{p}(\mathcal{H}^T)^F + \left(\tfrac{1}{2} - \eta\right) \widehat{p}(\mathcal{F}^T)^F + \eta \widehat{p}(\mathcal{F}^N)^F \tag{40}$$

$$\Delta \widehat{P} \equiv \widehat{P}^H - \widehat{P}^F = \frac{1 - 2\eta}{1 - \eta} \widehat{E}. \tag{41}$$

$$z \in \mathcal{H}^N : \quad \widehat{\widehat{p}}(z)^H = \widehat{\widehat{W}}^H \tag{42}$$

$$z \in \mathcal{H}^T : \quad \widehat{\widehat{p}}(z)^H = \widehat{\widehat{W}}^H \quad \wedge \quad \widehat{\widehat{p}}(z)^F = \widehat{\widehat{W}}^H - \widehat{\widehat{E}} \tag{43}$$

$$z \in \mathcal{F}^T : \quad \widehat{\widehat{p}}(z)^F = \widehat{\widehat{W}}^F \quad \wedge \quad \widehat{\widehat{p}}(z)^H = \widehat{\widehat{W}}^F + \widehat{\widehat{E}} \tag{44}$$

$$z \in \mathcal{F}^N : \quad \widehat{\widehat{p}}(z)^F = \widehat{\widehat{W}}^F \tag{45}$$

$$\Delta \widehat{\widehat{P}} \equiv \frac{1 - 2\eta}{1 - \eta} \widehat{\widehat{E}} + \frac{\eta}{1 - \eta} \Delta \widehat{\widehat{W}}. \tag{46}$$

Log-linearizing the aggregate intertemporal budget constraint Eq. (6) combined with the government constraint Eq. (8) under symmetric taxation gives

$$\left[f_t^j(i) - f_{t-1}^j(i)\right] \frac{P_t^T}{P_t^j} = r_{t-1} f_{t-1}^j(i) \frac{P_t^T}{P_t^j} + \frac{\theta}{\theta - 1} \frac{w(i)_t^j \mathbf{l}_t^j(i)}{P_t^j} - \mathbf{c}_t^j(i). \tag{47}$$

Let $\frac{1}{2}F^j \equiv \int_{\mathcal{H}} f^j(i)di$ denote the aggregate per capita current account balance and assume $f_0^j(i) = 0$. We can expresses the foreign asset position $\frac{1}{2}d\overline{F}^H \overline{P}_0^T$ relative to the value $\frac{1}{2}\overline{\mathbf{Y}}_0 \overline{p}_0^H$ of aggregate domestic output. Country differences $2d\overline{F}_0^H \overline{P}_0^T / \overline{\mathbf{Y}}_0 \overline{p}_0^H = d\overline{F}_0^H \overline{P}_0^T / \overline{\mathbf{Y}}_0 \overline{p}_0^H - d\overline{F}_0^F \overline{P}_0^T / \overline{\mathbf{Y}}_0 \overline{p}_0^H$ in the net foreign asset position follow as expressed in Eq.(23).

Appendix D: Solution

Recursive elimination reduces the system of equations to the following 3 relationships:

$$\begin{aligned}
\Delta\widehat{\overline{W}} &= \left[1 - \frac{\overline{r}}{2}\frac{\theta - 1 + \eta}{1 - \eta}\right] \Delta\widehat{P} + \left[1 + \frac{\overline{r}}{2}\frac{1 - 2\eta}{1 - \eta}\right] \Delta\widehat{C} + \frac{1}{2}\Delta\widehat{\overline{\kappa}} \\
k_3(\eta, \theta)\Delta\widehat{\overline{W}} &= (\theta + 1 - \eta)\, \Delta\widehat{P} + \Delta\widehat{C} + \frac{1}{2}(1 - \eta)\Delta\widehat{\overline{\kappa}} \\
0 &= \Delta\widehat{P} + \Delta\widehat{C} - \Delta\widehat{M},
\end{aligned}$$

or

$$\Delta\widehat{P} = k_1(\eta, \theta)\Delta\widehat{M} + k_2(\eta, \theta)\Delta\widehat{\overline{\kappa}},$$

where we define

$$\begin{aligned}
k_1(\eta, \theta) &= \frac{k_3(\eta, \theta)\left[1 + \frac{\overline{r}}{2}\frac{1 - 2\eta}{1 - \eta}\right] - 1}{\left[1 + \frac{\overline{r}}{2}\frac{k_3(\eta, \theta)}{1 - \eta}\right](\theta - \eta)} > 0 \\
k_2(\eta, \theta) &= \frac{\frac{1}{2}k_3(\eta, \theta) - (1 - \eta)}{\left[1 + \frac{\overline{r}}{2}\frac{k_3(\eta, \theta)}{1 - \eta}\right](\theta - \eta)} > 0 \\
k_3(\eta, \theta) &= (1 + \theta)(1 - \eta) - \frac{\eta^2(\theta - 1)}{(1 - \eta)} > 0.
\end{aligned}$$

We verify that the real exchange rate effect

$$\widehat{E} - \Delta\widehat{P} = \frac{\eta}{1 - 2\eta}k_1(\eta, \theta)\Delta\widehat{M} + \frac{\eta}{1 - 2\eta}k_2(\eta, \theta)\Delta\widehat{\overline{\kappa}}$$

is decreasing in the openness 2η for fixed values $\theta > 1$, $\Delta\widehat{M} > 0$, $\Delta\widehat{\overline{\kappa}} > 0$).

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Table 1:

Price Notation

Countries Home (H) and Foreign (F) both produce a set of tradeable and nontradeable products with the respective price set in local currency

Product Origin	Country H		Country F	
Product Type	Nontraded	Traded	Traded	Nontraded
Product Index	$z \in \mathcal{H}^N$	$z \in \mathcal{H}^T$	$z \in \mathcal{F}^T$	$z \in \mathcal{F}^N$
Country H	$p(z)_t^H$	$p(z)_t^H$	$p(z)_t^H$	
Country F		$p(z)_t^F$	$p(z)_t^F$	$p(z)_t^F$

Table 2:

Full Sample

The effective real exchange rate volatility (measured as the standard deviation of 3 year tradeweighted exchange rate changes) for the full sample is regressed on variables comprising the inverse of the import share, the log per capita GDP (1980), the average inflation rate (1973-1990), a dummy for the number of revolutions and coups (Barro (1991)) and a dummy varaible for countries with exchange rate commitments in 1995 according to the International Financial Statistics (1996). We indicate significance on a 10 percent (*), 5 percent (**) and 1 percent level (***).

	(1)	(2)	(3)	(4)
Constant	0.031*	0.302***	0.265***	0.342***
	(0.018)	(0.058)	(0.060)	(0.058)
$[\text{Imports/GDP}]^{-1}$	0.014***	0.011***	0.008**	0.009**
	(0.004)	(0.004)	(0.003)	(0.004)
Log per capita GDP	-	−0.074***	−0.047***	−0.077***
		(0.015)	(0.015)	(0.015)
Av. inflation	-	-	0.059**	-
			(0.024)	
Revolutions	-	-	0.073*	-
			(0.040)	
FX commitment	-	-	-	−0.035**
				(0.014)
$\overline{R}^2$	0.164	0.414	0.558	0.467
Sample size	54	54	54	54

Table 3:

OECD Sample

The effective real exchange rate volatility (measured as the standard deviation of 3 year tradeweighted exchange rate changes) for the OECD subsample is regressed on variables comprising the inverse of the import share, the log per capita GDP (1980), a measure of central bank independence (Cukierman et al. (1992)) and a dummy varaible for countries with exchange rate commitments in 1995 according to the International Financial Statistics (1996). We indicate significance on a 10 percent (*), 5 percent (**) and 1 percent level (***).

	(1)	(2)	(3)	(4)
Constant	0.020***	0.134	0.129**	0.220**
	(0.006)	(0.104)	(0.092)	(0.089)
$[\text{Imports/GDP}]^{-1}$	0.006***	0.007***	0.006***	0.005***
	(0.001)	(0.001)	(0.001)	(0.001)
Log per capita GDP	-	−0.029	−0.024	−0.048**
		(0.027)	(0.024)	(0.023)
CB independence	-	-	−0.044**	-
			(0.017)	
FX commitment	-	-		−0.018***
				(0.005)
$\overline{R}^2$	0.470	0.476	0.596	0.654
Sample size	21	21	21	21

Table 4:

Instrumental Variable Estimates

Land area of a country (in logs) is used as an instrument for openness to estimate the relation between the effective real exchange rate and variables comprising the inverse of import share, the log per capital GDP (1980) and a dummy varaible for countries with exchange rate commitments in 1995 according to the International Financial Statistics (1996). We indicate significance on a 10 percent (*), 5 percent (**) and 1 percent level (***).

	(1)	(2)	(3)	(4)
Sample	Full	Full	OECD	OECD
Constant	0.295***	0.348***	0.169	0.227**
	(0.066)	(0.070)	(0.111)	(0.086)
$[\text{Imports/GDP}]^{-1}$	0.013**	0.008	0.009***	0.006***
	(0.006)	(0.007)	(0.002)	(0.002)
Log per capita GDP	−0.073***	−0.078***	−0.041	−0.051**
	(0.016)	(0.015)	(0.029)	(0.022)
FX commitment	-	−0.036**	-	−0.016***
		(0.016)		(0.006)
$\overline{R}^2$	0.413	0.466	0.407	0.641
Sample size	54	54	21	21

Table 5:

Volatility at Higher Frequencies

The effective real exchange rate volatility is measured as the standard deviation of tradeweighted exchange rate changes for the OECD subsample for the following frequencies: 1 month (1), 3 months (2), 12 months (3) and 36 months (4). The independent variable is the inverse of the import share. We indicate significance on a 10 percent (*), 5 percent (**) and 1 percent level (***).

	(1)	(2)	(3)	(4)
Constant	0.0066***	0.0113***	0.0174***	0.0197***
	(0.0020)	(0.0027)	(0.0039)	(0.0064)
$[\text{Imports/GDP}]^{-1}$	0.00007	0.0010	0.0024**	0.0062***
	(0.00045)	(0.0006)	(0.0009)	(0.0014)
$\overline{R}^2$	−0.051	0.082	0.246	0.470
Sample size	21	21	21	21

Table 6:

Relative Price Volatility

The volatility of the relative price levels are caluculated based on tradeweights between OECD countries and regressed on variables comprising the inverse of the import share, the log per capita GDP (1980), the average inflation rate (1973-1990), a measure of central bank independence (Cukierman et al. (1993)) and a dummy varaible for countries with exchange rate commitments in 1995 according to the International Financial Statistics (1996). We indicate significance on a 10 percent (*), 5 percent (**) and 1 percent level (***).

	(1)	(2)	(3)
Constant	0.016*	0.350***	0.384***
	(0.008)	(0.076)	(0.080)
Imports/GDP	0.017	−0.003	0.008
	(0.023)	(0.017)	(0.019)
Log per capita GDP	-	−0.084***	−0.093***
		(0.019)	(0.020)
CB independence	-	-	0.005
			(0.015)
FX commitment	-	-	−0.007
			(0.005)
$\overline{R}^2$	−0.025	0.492	0.489
Sample size	20	20	20

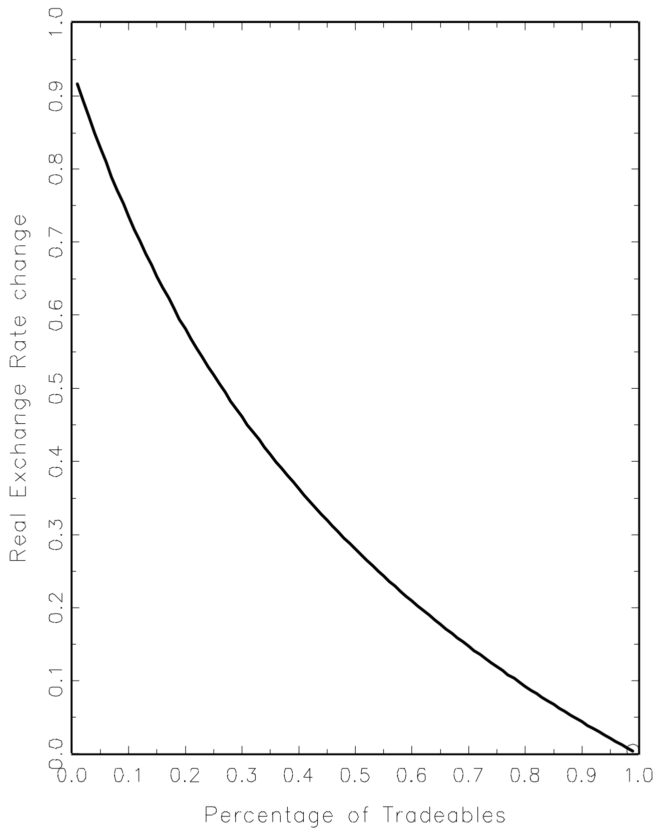

Figure 1: Real exchange rate depreciation of a one percent increase in the relative money supply as a function of the openness of the economy. The parameters are $\theta = 6$ and $r = 0.07$.

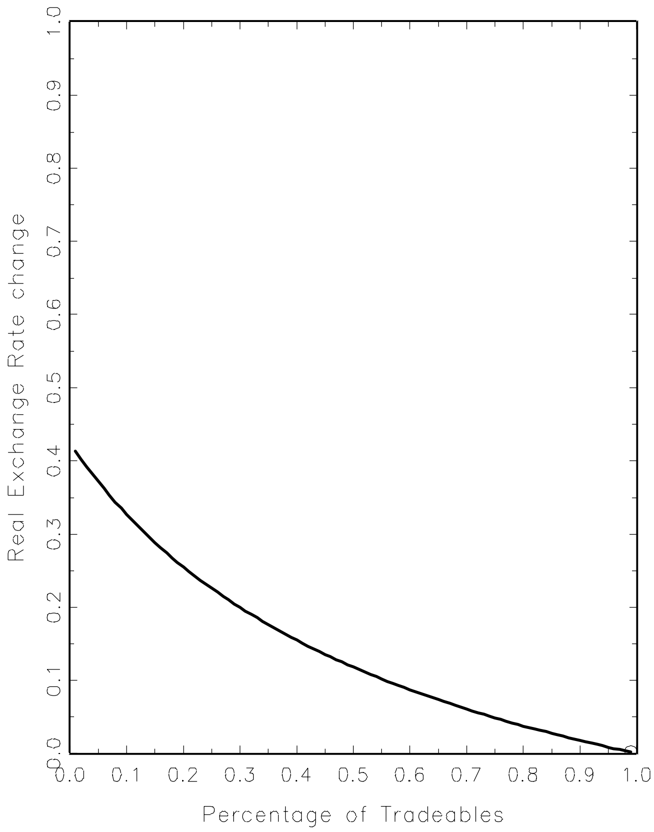

Figure 2: Real exchange rate depreciation of a one percent unanticipated decrease in the relative factor supply as a function of the openness of the economy. The parameters are $\theta = 6$ and $r = 0.07$.

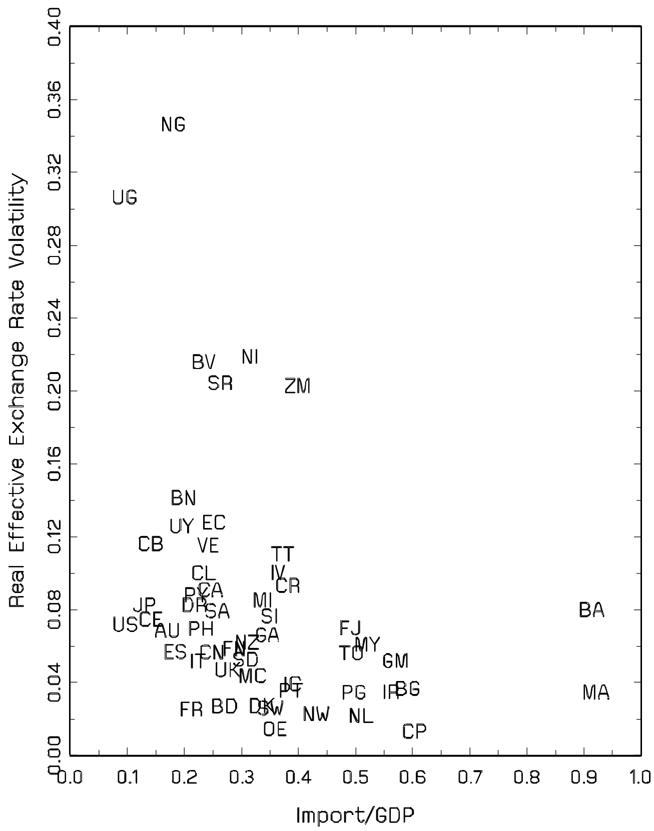

Figure 3: Volatility of the real effective exchange rate for the full sample of 54 countries as a function of the import share. For the nemonics of the OECD countries see Figure 4. The non-OECD countries are Bahrain (BA), Bolivia (BV), Burundi (BN), Cameroon (CA), Central Africa Rep.(CE), Chile (CL), Colombia (CB), Costa Rica (CR), Cyprus (CP), Doninican Rep. (DR), Ecuador (EC), Fiji (FJ), Gabon (GA), Gambia (GM), Ivory Coast (IV), Malawi (MI), Malaysia (MY), Malta (MA), Morocco (MC), Nicaragua (NI), Nigeria (NG), Papua New Ginea (PG), Paraguay (PY), Philippines (PH), Saudi Arabia (SI), Sierre Leone (SR), South Africa (SA), Togo (TO), Trinidad & Tobago (TT), Uganda (UG), Uruguay (UY), Venezuela (VE), Zambia (ZM).

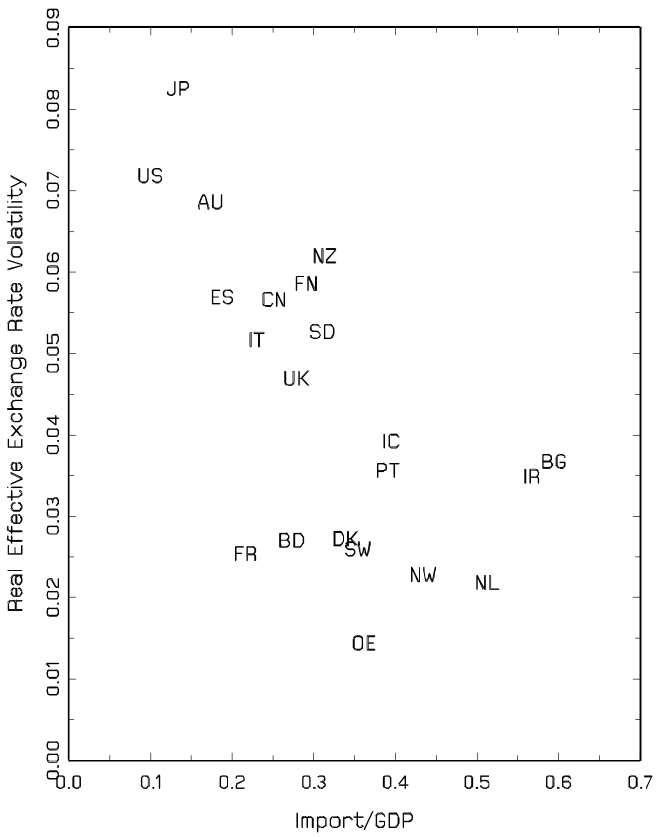

Figure 4: Volatility of the real effective exchange rate for 21 OECD countries as a function of the import share. The countries are Australia (AU), Austria (OE), Belgium (BG), Canada (CN), Denmark (DK), Finland (FN), France (FR), Germany (BD), Iceland (IC), Ireland (IR), Italy (IT), Japan (JP), Netherlands (NL), New Zealand (NZ), Norway (NW), Portugal (PT), Spain (ES), Sweden (SD), Switzerland (SW), United Kingdom (UK) and United States (US).

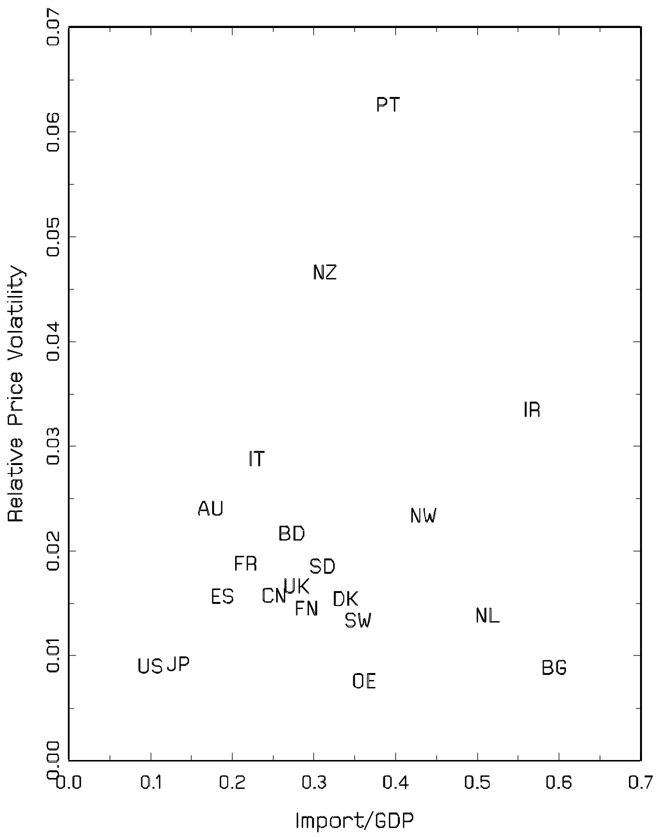

Figure 5: Volatility of the relative price level for 20 OECD countries as a function of openness. The nemonics are explained in Figure 4.