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Exchange rates as shock absorbers: The role of export margins

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ABSTRACT

This study addresses the role of floating exchange rates as shock absorbers when trade involves previously traded goods (intensive margin) as well as new goods and previously non-traded goods (extensive margin). In a panel VAR model of 23 developed economies, we first document that adjustment to real shocks occurs mainly at the extensive margin and particularly so in fixed regimes. This in turn amplifies output fluctuations. We then propose a model with firm entry and endogenous selection of exporters that generates dynamics in line with the estimated responses.

1. Introduction

As is well-known since Friedman (1953), a major advantage of flexible exchange rates over fixed rates is based on the fact that, in a world with sticky prices, the nominal exchange rate could be used to insulate the economy against real shocks. When economies are hit by a real shock, the argument goes, flexible rates allow to adjust relative prices more quickly and imply smoother adjustment in terms of quantity. In flexible regimes, one should therefore observe smoother quantity responses and quicker adjustment in relative prices compared to fixed regimes. Evidence on the shock absorption property of floating regimes abounds.[1] These studies are based on the implicit premise that all adjustment occurs at the intensive margin, with changes in the volume of previously traded goods. This stands in contrast to recent evidence showing that a relevant fraction of the growth in trade volumes occurs at the extensive margin, with export of new products and previously non-traded goods (see Kehoe and Ruhl, 2013). In principle, changes in tradability can affect the transmission of shocks in the world economy. An increase in the number of exporters, for instance, induces a tendency for poorer countries to have lower overall price levels than richer countries, what Ghironi and Mélitz (2005) dub an "endogenous Balassa–Samuelson effect" (see also Bergin et al., 2006). Moreover, it leads to stronger terms of trade and a worsening of the European external balance in the aftermath of market reforms in Europe (Cacciatore et al., 2015).[2] The extent to which endogenous changes in entry affect the shock absorption property of flexible rates is, however, unclear. This paper addresses the question both empirically and theoretically.

First, we document the cyclical properties of export margins in a sample of 23 developed economies over the period 1988–2011. Four facts stand out: (1) Extensive margins are far less volatile than intensive margins. (2) Trade margins are almost acyclical and positively correlated with each other. (3) Extensive margins are less volatile in countries with fixed

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[1] Early studies include Baxter and Stockman (1989), Flood and Rose (1995), Bayoumi and Eichengreen (1994), Broda (2004), Levy-Yeyati and Sturzenegger (2003), and Ghosh et al. (1997) among others.

[2] Lewis and Winkler (2015) focus on the transmission of government expenditure shocks.

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exchange rates than in countries with floating rates. (4) The volatility of intensive margins is almost identical across exchange rate regimes.

Then, we investigate the dynamics of output and export margins in fixed and floating regimes based on a panel VAR approach. In order to focus on the Friedman's hypothesis, the analysis is restricted to a single real shock given by the terms of trade of a country.[3] The vector of endogenous includes the terms of trade and output of the exporting country together with extensive and intensive margins measured on a country-pair basis. Identification of structural shocks is achieved by assuming a contemporaneous recursive ordering where the variables are ordered as given in the definition of the endogenous vector. This entails the assumption that the terms of trade are exogenous, i.e. they cannot react contemporaneously to innovations in the other variables in the system. Evidence is provided suggesting that the terms of trade can be treated as exogenous for the sample of developed economies examined.

We find that a positive shock raises exports along the extensive margins in both fixed and floating regimes. The effect on exports of previously traded goods is, on the contrary, negligible. Moreover, the average response of extensive margins in the sample of peggers is around 3 times as large as the average response among floaters. Interestingly, a large response of extensive margins is associated with a large output effect.

Finally, we propose a two-country dynamic, general equilibrium model with firm entry that helps explain these facts. The model extends the setup in Cavallari (2013) so as to allow for the endogenous selection of exporters: while all firms serve domestic markets, only a subset of these firms will export. The share of exporters is determined endogenously in the model by striking a balance between firm-specific export costs and export profits.

Simulations show that an increase in the price of exports raises output and consumption at home while reducing them abroad. In contrast to productivity shocks, which spread their effects symmetrically in the world economy, a shock to the terms of trade implies a redistribution of wealth across countries. Interestingly, a positive shock discourages the creation of new products. The reason is expenditure switching in favour of cheaper foreign goods, which reduces the profitability of new businesses at home. This in turn reduces the range of products that will be exported for a given share of exporters. On the other hand, a larger share of firms operating in domestic markets may find it profitable to export when export prices increase. Which one of these opposing effects prevails depends crucially on the exchange rate regime: the number of exporters (the extensive margin) rises in fixed regimes while it reduces in floating regimes. Our clue is that potential exporters have a strong incentive to trade previously non-traded goods when exchange rate variability is eliminated over the whole investment horizon.

In line with the estimated responses, in our model extensive margins increase after a positive shock of the terms of trade. Moreover, they react more aggressively than intensive margins and particularly so in fixed regimes. The reason is shock absorption in flexible regimes. The depreciation of the home currency allows to partly counteract the appreciation in the terms of trade, thereby smoothing adjustment at the extensive margin. This in turn helps smoothing output.

The remainder of the paper is organized as follows. Section 2 presents new empirical evidence on export margins and exchange rates. Section 3 presents the theoretical model with its log linear approximation in Section 4. Section 5 concludes. Appendix A contains the steady state of the model and the log-linearized equations. Appendix B contains details on data and estimation.

2. Empirical analysis

In this section, we first present descriptive statistics for export margins in 23 OECD economies over the period 1988–2011. We find that: (1) Extensive margins are less volatile than GDP while intensive margins are more volatile than GDP. (2) Margins are almost acyclical and positively correlated with each other. (3) Extensive margins are less volatile in countries with fixed exchange rates than in countries with floating rates. (4) The volatility of intensive margins is almost identical across exchange rate regimes. Then, we investigate the dynamics of output and export margins in response to terms of trade shocks in fixed and floating regimes.

2.1. Data

Our sample includes 23 developed countries over the period from 1988 to 2011. GDP – measured in domestic currency at constant prices – is from the OECD StatExtracts database. Terms of trade are from the IFS-IMF database or the World Bank Data upon availability. The terms of trade are defined as the price of a country's exports towards the world relative to the price of its imports from the world. An increase in the terms of trade is therefore an appreciation. All variables are logged.

Export margins are from the UN Comtrade database. They are calculated with the World Integrated Trade Solution of the World Bank from bilateral trade measures at the four-digit Standard International Trade Classification.[4] Following

[3] In a related study (Cavallari and D'Addona, 2015), we provide evidence about the transmission of external real and nominal shocks. We document that adjustment to both these shocks involves mainly the extensive margin in fixed regimes.

[4] http://wits.worldbank.org/wits/.

Hummels and Klenow (2005), the extensive margin of exports from country j to country m is defined as

$$XM_m^j = \frac{\sum_{i \in I_m^j} X_{m,i}^W}{X_m^W} \tag{1}$$

where $X_{m,i}^W$ is the export value from the world to country m of category i, I_m^j is the set of observable categories in which country j has positive exports to country m, and X_m^W is the aggregate value of world exports to country m. The extensive margin is a weighted sum of country j's exported categories relative to all categories exported to country m, where categories are weighted by their importance in world's exports to country m. By construction XM_m^j is comprised between 0 and 1, with higher values reflecting a larger variety of categories exported.

The intensive margin of exports from country j to country m is defined as

$$IM_m^j = \frac{X_m^j}{\sum_{i \in I_m^j} X_{m,i}^W} \tag{2}$$

where X_m^j is the total export value from country j to country m. The intensive margin is the value of j' s exports to country m relative to the weighted categories in which country j exports to country m. IM_m^j is defined between 0 and infinity, where 0 means that country j has not previously exported to country m, and higher values reflect a larger volume of exports within previously traded goods. By definition, the country j's share of world exports to country m is given by the product of intensive and extensive margins

$$Sh_m^j = \frac{X_m^j}{X_{m,i}^W} = XM_m^j IM_m^j \tag{3}$$

The measurement implies that for a given level of a country j's share in world exports to country m, the extensive margin would be higher if country j exports many different categories of products to country m whereas the intensive margin would be higher if it only export a few categories of products to country m.

2.2. Descriptive statistics

Consider country-specific margins, given by aggregation of bilateral margins across destinations. The extensive margin of, say, Italy is a simple average of the extensive margins of Italy's exports to all other countries in the sample. It provides a measure of the broadness of Italy's exported varieties in intra-OECD trade. Similarly, the intensive margin of Italy is an

Table 1
Export margins. This table reports key statistics for export margins in 23 OECD countries over the period (1988–2011). The first three columns report the ratio of the standard deviation of export margins to the standard deviation of GDP while the last three columns report their correlations with GDP.

Country	ST.DEV. (ratio to GDP)			Correlation with GDP		
	Ext. margin	Int. margin	Ex. share	Ext. margin	Int. margin	Ex. share
Australia	0.352	4.743	0.041	0.040	0.046	0.044
Belgium	0.334	3.307	0.029	0.196	0.044	0.108
Canada	0.770	13.581	0.134	−0.116	−0.227	−0.227
Czech Republic	0.221	2.605	0.019	−0.023	−0.074	−0.067
Denmark	0.332	5.305	0.044	0.189	0.062	0.160
Finland	0.236	4.276	0.029	0.163	−0.026	−0.013
France	0.323	3.545	0.031	0.261	0.115	0.195
Germany	0.276	2.829	0.027	0.364	0.117	0.203
Iceland	0.331	9.693	0.055	0.208	−0.050	0.080
Italy	0.406	2.886	0.025	0.159	−0.001	0.068
Japan	0.482	5.960	0.048	0.120	0.117	0.150
Korea, Rep.	0.279	3.387	0.026	0.199	−0.084	0.000
Luxembourg	0.554	15.773	0.083	−0.131	0.110	0.076
Mexico	0.201	7.460	0.043	0.114	0.057	0.072
Netherlands	0.363	3.675	0.030	0.015	0.097	0.097
New Zealand	0.270	4.343	0.034	0.226	0.071	0.110
Norway	0.405	7.119	0.054	0.104	0.038	0.063
Portugal	0.469	9.150	0.063	−0.123	0.085	0.057
Spain	0.382	4.349	0.035	0.342	−0.120	0.040
Sweden	0.220	2.907	0.025	0.153	0.046	0.104
Switzerland	0.400	6.345	0.047	0.021	0.162	0.193
United Kingdom	0.316	4.065	0.035	0.045	0.084	0.103
United States	2.218	15.538	0.129	−0.062	−0.217	−0.242
Mean	0.441	6.210	0.047	0.107	0.020	0.060
Volatility	0.407	3.992	0.030	0.140	0.105	0.114

Table 2
Peggers and floaters. This table shows key statistics for export margins in the sub-samples of peggers and floaters. The *F*-test for the equality of standard deviations between the two groups is also reported. The classification of the exchange rate regimes is based on Born et al. (2013).

Extensive margins	Obs.	Mean	Std. dev.
Floaters	8954	0.6535	0.2304
Peggers	2001	0.7427	0.2142
$f=\sigma(Floats)/\sigma(Pegs)$			1.1563
Dof			(8953,2000)
$2{*}\Pr(F>f)$			0.0000
Intensive margins	Obs.	Mean	Std. dev.
Floaters	8954	3.6620	7.0789
Peggers	2001	6.5722	7.1714
$f=\sigma(Floats)/\sigma(Pegs)$			0.9744
Dof			(8953,2000)
$2{*}\Pr(F>f)$			0.4520
Share	Observations	Mean	Std. dev.
Floaters	8954	0.0298	0.0651
Peggers	2001	0.0551	0.0641
$f=\sigma(Floats)/\sigma(Pegs)$			1.0311
Dof			(8953,2000)
$2{*}\Pr(F>f)$			0.3862

average measure of the intensity of Italy's exports in intra-OECD trade. Table 1 provides descriptive statistics for margins and export shares in our sample. As is usual in business cycle studies, all variables are HP filtered with a smoothing parameter of 6.25.

Extensive margins are less volatile than output in all countries except the US as are export shares. The standard deviation of extensive margins relative to the standard deviation of GDP is 0.44 on average. Intensive margins, on the contrary, are far more volatile than GDP: the relative standard deviation is 6.21 on average. A low volatility of extensive margins may reflect the presence of sunk entry costs. Export margins and export shares are almost acyclical in many countries in our sample. On average, correlation with output is equal to 0.11, 0.02 and 0.06 for, respectively, extensive margins, intensive margins and export shares. Intensive and extensive margins are positively correlated between each other (not shown in Table 1).

Given the scope of the study, which is focused on the role of exchange rates in macroeconomic adjustment, we aggregate bilateral margins also by exchange rate regime. We consider two groups of countries: peggers and floaters (see Appendix B for the list of peggers and floaters). The group of "peggers" includes country pairs with a fixed exchange rate regime, i.e. to be included among the peggers both origin and destination countries must adopt fixed exchange rates according to the IMF de facto classification (see Ghosh et al., 1997), which we extend to match our sample period. Specifically, we consider an exchange rate regime of "pegged within horizontal bands" or tighter as a fixed exchange rate (values of 1–7 in the fine classification). All remaining regimes are classified as floating exchange rates. The group of peggers contains 110 country pairs among 11 European countries, including 2 countries which are not members of the monetary union. It reflects intra-European trade. The sample of "floaters" includes pairs with a flexible exchange rate, i.e. to be included among the floaters at least one country must adopt a flexible exchange rate regime in the IMF de facto classification. Note that in our sample, the de facto classification gives an identical split as the IMF de jure classification. Table 2 shows descriptive statistics in the sample of peggers and in the sample of floaters.

The volatility of extensive margins is lower among peggers than among floaters in a two-tailed *F*-test on the variance ratio (cf. Table 2). There is no remarkable difference between peggers and floaters as long as the volatility of intensive margins and export shares are concerned. These statistics suggest considerable variation of trade of new goods and trade of previously non-traded goods across exchange rate regimes. Trade of previously traded goods, on the contrary, does not appear to be affected by the exchange rate regime.

2.3. The VAR model

This section models the dynamics of extensive and intensive margins, together with real GDP and the terms of trade, TOT, in fixed and floating regimes. Consider the fixed-effect panel VAR model given by

$$A_0 Y_{j\times m,t} = A(L)Y_{j\times m,t} + f_{j\times m} + d_t + e_{j\times m,t} \tag{4}$$

where $j=1,2,\ldots 23$ denotes the exporting country, $m=1,2,\ldots 22$ with $m\neq j$ denotes the destination country, and t is time. The 4×1 vector of stationary endogenous variables $Y_{j\times m,t}$ contains terms of trade and output growth of the exporting country together with extensive and intensive margins measured on a country-pair basis, i.e. $Y_{j\times m,t} = (\Delta \log TOT_{j,t}, \Delta \log GDP_{j,t}, XM_{j\times m,t}, IM_{j\times m,t})$ where Δ denotes the first-difference operator. $f_{j\times m}$ is a vector of country-pair fixed effects; d_t are time dummies; $A(L)$ are matrix polynomials in the lag operator; and $e_{j\times m,t}$ is the vector of errors in the system with variance Ω.

Fixed effects $f_{j\times m}$ are included to account for individual heterogeneity in the panel. Since these effects may be correlated with the regressors through the lags of the dependent variables, usual mean-differencing provides biased estimates. To avoid the problem we use forward mean-differencing with the Helmert transformation (see Arellano and Bover, 1995). This procedure removes the forward mean, i.e. the mean of all the future observations for each country pair and year. Since this transformation preserves the orthogonality between transformed variables and lagged regressors, we use lagged regressors as instruments and estimate our VAR model by system GMM (Love and Zicchino, 2006).[5] Time dummies, d_t, are included to capture business cycle conditions which affect all cross-section units at the same time. In the estimation, we will consider time fixed effects by subtracting the mean of each variable for each country and year.

Dynamic responses of endogenous to structural shocks can be identified once A_0 and Ω are recovered from the reduced-form estimation. Identification is achieved by assuming a contemporaneous recursive ordering where the variables are ordered as given in the definition of $Y_{j\times m,t}$.[6] This entails the assumption that the terms of trade are exogenous, i.e. they cannot react contemporaneously to innovations in the other variables in the system. The exogeneity of the terms of trade will be addressed soon. Moreover, innovations to export margins can affect output growth only with a one-year lag. This may in principle be justified by the fact that export margins reflect investments in new businesses and these are likely to affect output with some delay. In theoretical business cycle models, new investments typically entail a time-to-build lag. In practice, the recursive ordering in our VAR model has no implications for the qualitative properties of estimated responses.

2.4. Preliminary tests

A key assumption in our identification strategy is the exogeneity of the terms of trade. In principle, the assumption is likely to hold in small economies which exert a negligible influence on world prices. In practice, however, we will soon show that only a small fraction of countries in our sample effectively exert such an influence. This, in turn, suggests that the bias eventually introduced by assuming exogenous terms of trade is small.

We test the hypothesis that export margins and GDP Granger cause the terms of trade in our sample using the test developed by Dumitrescu and Hurlin (2012) for panel data. Accepting the null hypothesis of no Granger causality implies that GDP and export margins do not help forecast the terms of trade, i.e. terms of trade are exogenous in a time series sense. The null of no Granger causality could not be rejected in approximately 87% of panel units as long as extensive and intensive margins are concerned. The percentage of rejection reduces to 67% for GDP. Among major economies, terms of trade exogeneity fails in Canada, Germany and Japan. Our results are robust to the exclusion of these countries.

The model (4) rests on the assumption of stationarity. We therefore need to determine the stationary form of the variables that will be used. To this end we perform individual and panel unit root tests on the log of GDP, the log of the terms of trade, the level of extensive and the level of intensive margins. We use the log transformation whenever possible for two reasons. The first is its variance stabilizing property. The second is that if a logged variable has a unit root, its first difference has a straightforward interpretation as percentage change.

The individual unit root tests are the Augmented Dickey–Fuller (ADF) test applied on a series-by-series basis. The panel unit root test is the ADF test in the model with individual country effects as in Levin et al. (2002). All these tests depend on the specification of the deterministic part of the autoregressive equations. We verify the presence of a trend by testing the significance of the intercept in the following AR(2) equation for each variable X, country by country

$$\Delta X_t = \alpha + \phi X_{t-1} + \varphi_i \Delta X_{t-1} + \epsilon_t$$

When the null $H_0: \alpha = 0$ is not rejected, we conclude that X does not have a time trend. This is true for extensive margins and intensive margins. ADF equations for these variables are thus specified with an intercept. The null is rejected for GDP and terms of trade so that a trend is included in the ADF equations for these variables.

Individual unit root tests could not reject the existence of a unit root for output and the terms of trade in almost all countries. The hypothesis of a unit root is rejected when differenced data are considered. These results are confirmed by the panel unit root tests. We therefore conclude that output and the terms of trade are I(1). Individual and panel unit root tests allow to reject the null hypothesis of a unit root in all remaining data. We conclude that extensive margins and intensive margins are I(0).

The presence of non-stationary variables raises the question whether an error correcting specification, i.e. a VECM model, might be appropriate for describing the dynamics in the data. A linear combination of output and the terms of trade, the cointegrating vector, might be stationary implying the existence of a long-run relation between these variables. We provide a formal test of cointegration for output and the terms of trade based on the Westerlund ECM panel cointegration test (Westerlund, 2007). The null hypothesis of no cointegration could not be rejected against the alternative hypothesis that a cointegrating relation between output and the terms of trade exists for at least one country in the sample. Consequently,

[5] Note that in our model the number of regressors coincides with the number of instruments (i.e., the model is just-identified) so that system GMM is equivalent to a 2SLS estimation equation by equation.

[6] These restrictions imply that the coefficients a_{12}, a_{13}, a_{14}, a_{23}, a_{24} and a_{34} of A_0 are equal to zero.

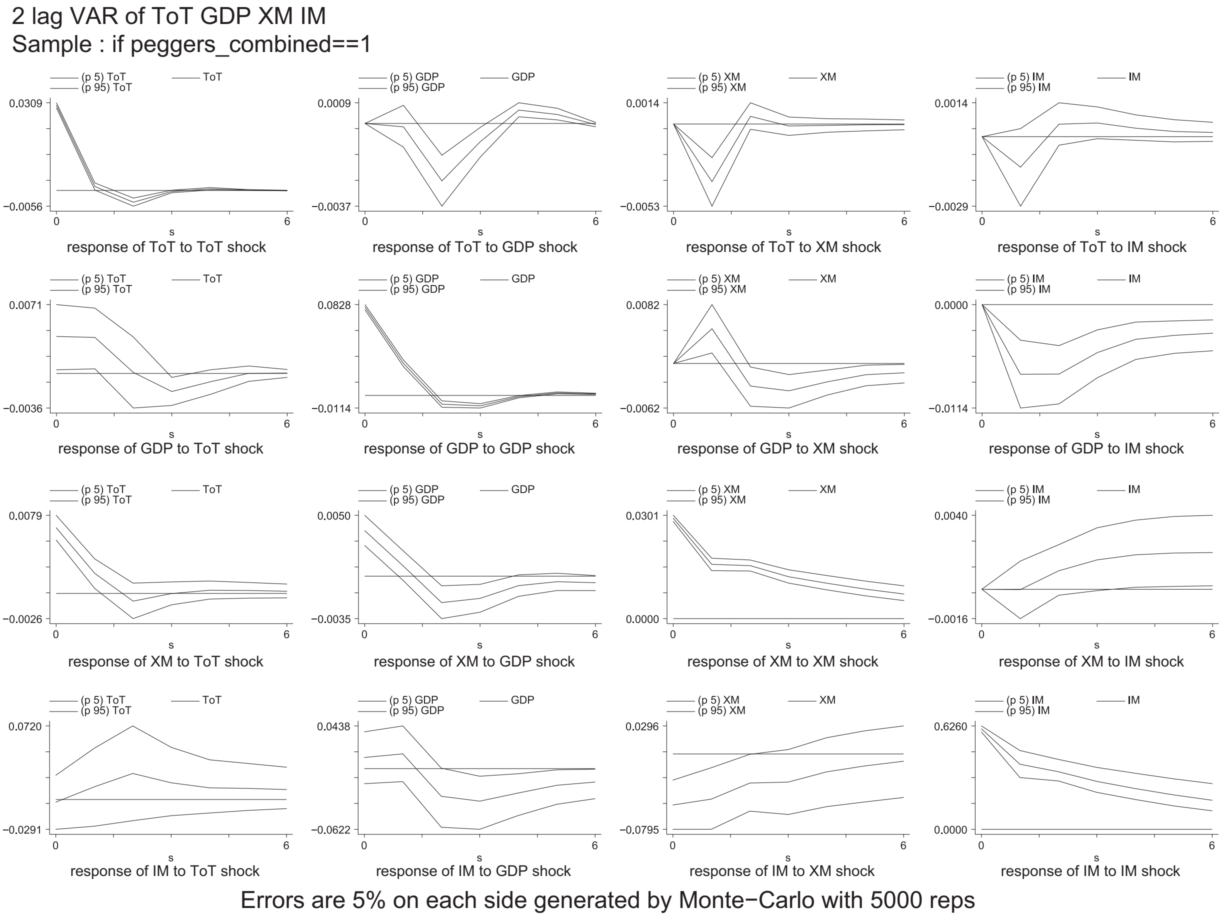

Fig. 1. Impulse responses and 90% confidence intervals in the sample of peggers.

estimating the VAR model in first differences for output and the terms of trade without imposing any cointegrating relation between these variables is a good approximation.

Finally, we use the Akaike Information Criterion (AIC) and the Schwartz's Bayesian information criterion (SBC) to determine how many lags of the dependent variables need to be included. In all panels, these criteria suggest including either two or three lags. We use a parsimonious two-lag specification, though we checked that using three lags would not lead to different conclusions.

2.5. Results

Given the scope of the study, which is focused on the role of exchange rates as shock absorbers, we split our sample into two groups according to the classification of the exchange rate regime described in the preceding section. In particular, the sample of "peggers" includes country pairs with a fixed exchange rate regime (i.e., to be included among the peggers both origin and destination countries must adopt a fixed exchange rate regime in our classification). The sample of "floaters" includes pairs with a flexible exchange rate (i.e. to be included among the floaters at least one country must adopt a flexible exchange rate regime in our classification). Then, we estimate the model separately for peggers and floaters.

Figs. 1 and 2 show average impulse responses to a one standard deviation rise in the terms of trade together with 90% confidence intervals generated by Monte Carlo simulations with 5000 replications in, respectively, the sample of peggers and the sample of floaters.

An appreciation in the terms of trade leads to an increase in extensive margins in both fixed and floating regimes. The effect is high on impact, then it gradually declines before becoming negligible after three years. The response of intensive margins is not significantly different from zero in both regimes. Adjustment seems to occur mainly at the extensive margin and particularly so in fixed regimes: the average response of XM in the sample of peggers is around 3 times as large as the response among floaters. Interestingly, a large response of extensive margins is associated with a large output effect. The cumulated increase in output growth is 4.8% on average in the sample of peggers and 2.4% in the sample of floaters.

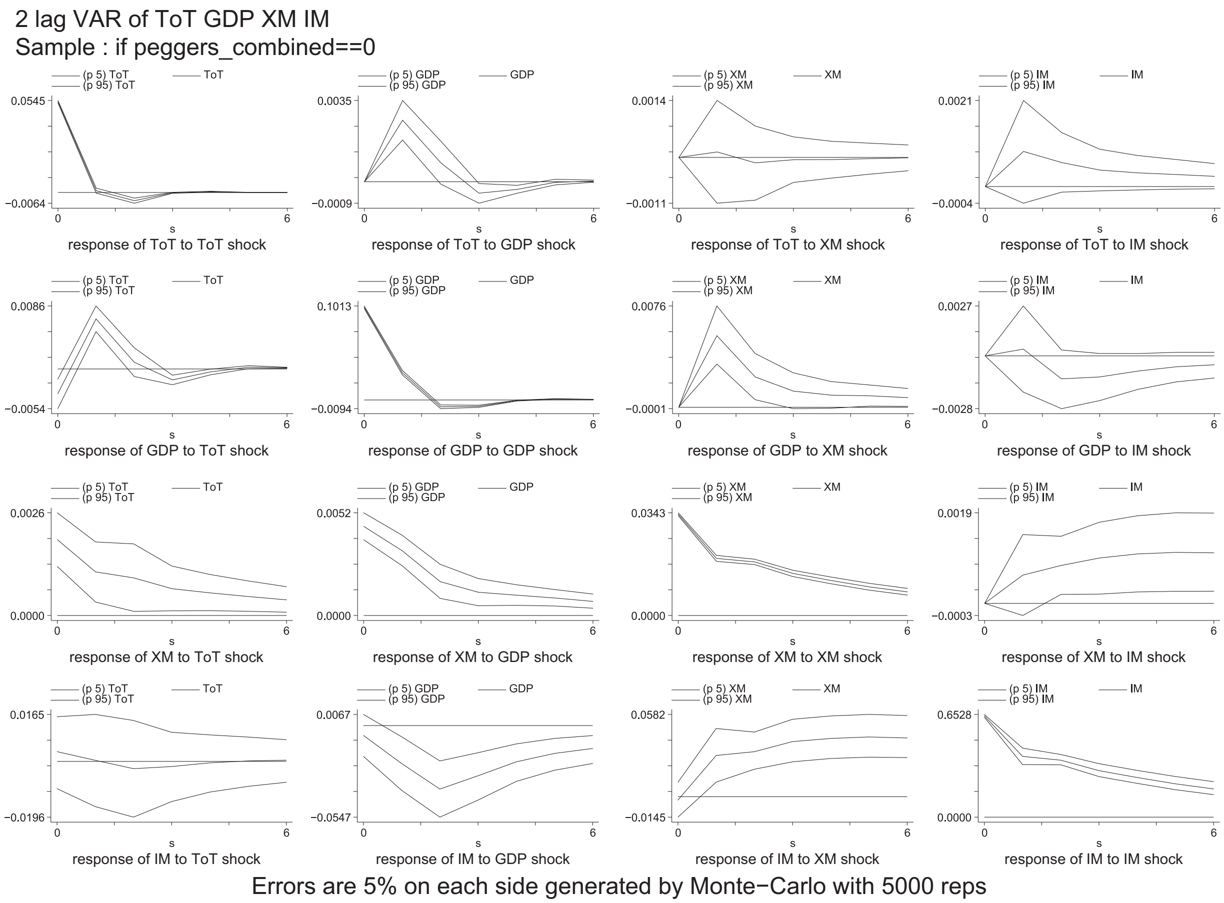

Fig. 2. Impulse responses and 90% confidence intervals in the sample of floaters.

Recent evidence documents a positive effect of exchange rate stability on the extensive margin of trade.[7] In a sample of European countries, Bergin and Lin (2012) find a significant rise in the extensive margin in anticipation of monetary unification, ahead of any rise in overall trade. The adoption of the euro, on the contrary, appears to have had no significant impact on the intensive margin of trade. A reason why exchange rate stability stimulates trade along the extensive margin (more than on the intensive margin) is the capacity to reduce uncertainty faced by potential exporters. When deciding whether to access foreign markets in the first place, investors strike a balance between expected revenues over the entire investment horizon and sunk entry costs. This in turn implies a strong incentive to enter whenever exchange rate risk is completely eliminated.[8] These studies are silent about the implications of trade of new goods and previously non-traded goods for shock absorption. The evidence presented above suggests that changes in the extensive margin may amplify the effects of terms of trade shocks. We now present a theoretical model in line with these facts.

3. Theoretical model

The model draws on Cavallari (2013). The world economy comprises two countries labelled Home, H, and Foreign, F, each populated by a continuum of agents of unit mass. Countries are specialized in the production of one type of good as in Corsetti and Pesenti (2001). Households supply labor services in competitive labor markets and consume a basket of domestic and imported goods. Goods markets are monopolistic competitive. Each firm produces a specific variety $h \in (0, N)$ of the Home good and a variety $f \in (0, N^*)$ of the Foreign good. In departing from Cavallari (2013), only a subset of domestic firms will export, N_X and N_X^* in, respectively, the Home and Foreign economy. The number of producers and the share of exporters are determined endogenously in the model. In our notation a star denotes a foreign variable. For ease of

[7] Auray et al. (2012) document an increase in the volatility of extensive margins after the adoption of the Euro.
[8] Theoretical models that examine the role of exchange rate risk for foreign market entry include, among others, Russ (2007) and Cavallari (2010).

exposition, we will refer to Home variables with the understanding that analogue conditions hold for the Foreign economy unless otherwise specified.

3.1. Households

Lifetime utility of the representative household is

$$\Omega_t = E_t\left[\sum_{s=t}^{\infty}\beta^{s-t}\left(\frac{(C_t)^{1-\rho}}{1-\rho}-\frac{\varphi\chi}{1+\varphi}(L_t)^{(1+\varphi)/\varphi}\right)\right] \tag{5}$$

where β is the subjective discount factor, $\rho>0$ is inter-temporal elasticity, $\varphi>0$ is the inverse of the Frisch elasticity of labor supply and E denotes the expectation operator. The consumption basket comprises domestic and imported goods

$$C=\frac{(C_D)^{\gamma}(C_X)^{1-\gamma}}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}} \tag{6}$$

where C_D, C_X are given by

$$C_D=\left[\int_0^N C_D(h)^{(\theta-1)/\theta}\,\mathrm{dh}\right]^{\theta/(\theta-1)}$$

$$C_X=\left[\int_0^{N_X^*} C_X(f)^{(\theta-1)/\theta}\,df\right]^{\theta/(\theta-1)} \tag{7}$$

and $\theta>1$ denotes the elasticity of substitution across varieties. The welfare-based consumer price index, CPI, is given by

$$P=(P_D)^{\gamma}(P_X)^{1-\gamma} \tag{8}$$

where

$$P_D=\left[\int_0^N p_D(h)^{1-\theta}\,dh\right]^{1/(1-\theta)}$$

$$P_X=\left[\int_0^{N_X^*} p_X(f)^{1-\theta}\,df\right]^{1/(1-\theta)} \tag{9}$$

and $p_D(h)$ and $p_X(f)$ denote the price of, respectively, the domestic and the imported variety both expressed in home currency (similarly, $p_D^*(f)$ and $p_X^*(h)$ are Foreign currency prices).

Exports entail iceberg-type transport costs so that for one unit of a good to reach the foreign market $1+\tau$ units must be shipped. In addition, we assume that firms let the final price of their product vary with the exchange rate at a constant elasticity η.[9] At each point in time, the Home-currency price of Home imports is therefore $p_{X,t}(f)=\varepsilon_t^{\eta}(1+\tau)p_{D,t}^*(f)$ where the nominal exchange rate ε is the price of the foreign currency in terms of the home currency. Similarly, the Foreign-currency price of Foreign imports is $p_{X,t}^*(h)=\varepsilon_t^{-\eta}(1+\tau)p_{D,t}(h)$. In this setting, $\eta=0$ implies local currency pricing, i.e. prices are determined in the consumers' currency and do not react to exchange rate changes. $\eta=1$ implies producers' currency pricing.[10] The home terms of trade, defined as the price of Home exports relative to Home imports, are given by $ToT_t=P_{X,t}^*\varepsilon_t/P_{X,t}+T_t$, where T_t is an exogenous shock. An increase in ToT_t is thus an appreciation.

Households enter each period with holdings of riskless bonds denominated in Home currency, B_t, and in foreign currency, B_t^*, and a share s_t of a mutual fund of domestic firms. The fund includes firms already operating at time t, N_t, and the new entrants $N_{e,t}$. Only $(1-\delta)(N_t+N_{e,t})$ of these firms will survive and pay dividend at the end of the period. Since households do not know which firm will be hit by the exogenous death shock δ at the end of the period, they finance all incumbents and new entrants during period t. The real value of a share in this fund is ν_t. Households receive labor income, interest income on domestic and foreign bonds at the risk-free nominal interest rates i_t and i_t^*, respectively, dividend income d_t on share holdings and the value of selling their initial share position. These resources are allocated between purchases of bonds and shares to be carried into next period and consumption. The budget constraint in real terms is

$$\frac{B_t}{P_t}+\frac{\varepsilon_t B_t^*}{P_t}+s_t(N_t+N_{e,t})v_t=\frac{B_{t-1}}{P}i_t+\frac{\varepsilon_t B_{t-1}^*}{P_t}i_t^*+(1-\delta)s_{t-1}N_t(v_t+d_t)+\frac{W_t}{P_t}L_t-C_t \tag{10}$$

where W_t is the nominal wage.

[9] Corsetti and Pesenti (2005) show that firms will optimally choose the price for exports in their own currency, recognizing that the final price may vary with the exchange rate. Given that demand elasticity is equal in domestic and foreign markets and that transport costs do not affect marginal profits, they will set $p_X(h)=p_D(h)$ and $p_X^*(f)=p_D^*(f)$.

[10] Ample evidence documents a degree of exchange rate pass-through to import prices well below unity (see Goldberg and Knetter, 1997 for early evidence). In more recent times the degree of pass-through has further declined (see Campa and Goldberg, 2005 and Gust et al., 2010).

Utility maximization with respect to C_t, B_t, B_t^*, s_t, and L_t implies the first order conditions

$$\beta E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\rho}\frac{i_{t+1}}{(1+\pi_{t+1})}\right]=1 \tag{11}$$

$$E_t\left[\frac{C_{t+1}^{-\rho}}{(1+\pi_{t+1})}\left(i_{t+1}-\frac{\varepsilon_{t+1}i_{t+1}^*}{\varepsilon_t}\right)\right]=0 \tag{12}$$

$$(C_t)^{-\rho}=\beta(1-\delta)E_t\left[\frac{d_{t+1}+v_{t+1}}{v_t}(C_{t+1})^{-\rho}\right] \tag{13}$$

$$\frac{W_t}{P_t}=\chi(L_t)^{1/\varphi}(C_t)^{\rho} \tag{14}$$

where $\pi_t=(P_t/P_{t-1})-1$ is the CPI inflation rate.

As agents have access to local and foreign bonds, financial markets are perfectly integrated and the uncovered interest parity, UIP, holds, i.e. $E_t(\varepsilon_{t+1}/\varepsilon_t)=(1+i_{t+1})/(1+i_{t+1}^*)$. Furthermore, combining the bond Euler equation for Home households (12) with the equivalent condition for Foreign households and using UIP yields the risk-sharing condition

$$\left(\frac{C_t}{C_t^*}\right)^{\rho}=q_t$$

where $q_t=P_t^*\varepsilon_t/P_t$ is the real exchange rate.

In our model, purchasing power parity, PPP, would hold absent export costs and imperfect pass-through. Suppose that there are no export costs, that $\tau=0$ and $\eta=1$. All firms will export and there will be no non-traded goods: $N_t=N_{X,t}$ and $N_t^*=N_{X,t}^*$. It is immediate to see that $q_t=1$ in all periods. Assuming further a given number of firms at home and abroad, so that N_t/N_t^* is constant, the model is isomorphic to Corsetti and Pesenti (2001)'s setup. In this framework, the mechanism of adjustment to shocks in the world economy hinges exclusively on the terms of trade. A, say, productivity rise at home spreads its positive effects abroad through the deterioration in the home terms of trade (a fall in ToT_t). Foreign consumption increases for a given level of real income, leaving relative consumption and the real exchange rate unaltered. As it will be evident soon, in our setup with entry the productivity rise induces the creation of new products at home. This in turn depreciates the home currency in real terms (q_t rises), absorbing part of the movement in foreign consumption.

Finally, optimal demands for home and foreign varieties are given by

$$\begin{aligned}C_{D,t}(h)&=\left(\frac{p_{D,t}(h)}{P_t}\right)^{-\theta}\gamma\left(\frac{P_{D,t}}{P_{X,t}}\right)^{\gamma-1}C_t\\ C_{X,t}(f)&=\left(\frac{p_{X,t}(f)}{P_t}\right)^{-\theta}(1-\gamma)\left(\frac{P_{D,t}}{P_{X,t}}\right)^{\gamma}C_t\end{aligned} \tag{15}$$

3.2. Firms

Firms face a linear technology with labor as the sole factor

$$y_t(h)=Z_tL_t(h) \tag{16}$$

where Z is a country-specific shock to labor productivity. All firms produce for the domestic market while only a subset of these firms serve foreign markets. We first determine the total number of firms in the economy, N_t. Given N_t, we then determine the share of exporters.

Prior to entry, firms face an exogenous sunk entry cost. Entry requires purchasing $f_{e,t}$ units of a combination of domestic and imported goods $f_{e,t}=\frac{(C_{D,t})^{\sigma}(C_{X,t})^{1-\sigma}}{\sigma^{\sigma}(1-\sigma)^{1-\sigma}}$ at the price $P_{f,t}=(P_{D,t})^{\sigma}(P_{X,t})^{1-\sigma}$ with $\sigma\in(0,1)$. The cost of entry in units of consumption is thus $f_{e,t}\frac{P_{f,t}}{P_t}$. Note that the composition of the investment basket may differ from that of the consumption basket.[11] Other studies, as Bilbiie et al. (2012) and Cavallari (2007), specify entry costs as wages. As is now well-understood, entry costs may have important consequences for the capacity of theoretical economies to reproduce an empirically plausible dynamics, especially in monetary models.[12] In these models, entry costs as wages have the unappealing consequence of implying a positive relation between firms' entry and interest rate innovations in contrast to what found in the data.[13] For this motive, Bergin and Corsetti (2008) propose entry costs in terms of goods, as is done in our model, while Lewis and Poilly (2012) consider wage rigidity.

[11] Clearly, when $\theta=\sigma$ entry costs are constant in real terms (i.e. in units of consumption), a case examined by Auray and Eyquem (2011) and Bilbiie et al. (2007).

[12] See Cavallari (2013, 2015).

[13] Uuskula (2010) shows that a 1% increase in the Federal Funds rate leads to a 0.6% fall in the entry rate. See also Bergin and Corsetti (2008) and Lewis and Poilly (2012).

The dynamics of entry follows Ghironi and Mélitz (2005). All firms entered in a given period are able to produce in all subsequent periods until they are hit by a death shock, which occurs with a constant probability $\delta \in (0,1)$. Therefore, a firm entered in period t will only start producing at time $t+1$. In each period, in addition to incumbent firms there is a finite mass of entrants, $N_{e,t}$. Entrants decide to start a new firm whenever its real value, ν_t, given by the present discounted value of the expected stream of profits $\{d_s\}_{s=t+1}^{\infty}$, covers entry costs

$$\nu_t = E_t\left[\sum_{s=t+1}^{\infty} \beta(1-\delta)\left(\frac{C_{s+1}}{C_s}\right)^{-\rho} d_s\right] = f_{e,t}\frac{P_{f,t}}{P_t} \tag{17}$$

The timing of entry and the one-period production lag imply the following law of motion for producers

$$N_t = (1-\delta)(N_{t-1}+N_{e,t-1}) \tag{18}$$

Given the total number of firms in the economy, we can determine the subset of these firms that will sell their products also in foreign markets, $N_{X,t}$. Access to foreign markets requires purchasing $f_{x,t}$ units of the composite investment good defined above at the price $P_{f,t}$. This cost is independent of the volume of exports and, differently from the entry cost, it is paid on a period by period basis. Following (Bergin et al., 2006), we consider heterogeneous export costs. Specifically, we assume that at the beginning of the period, before production takes place, each firm draws a firm-specific export cost $f_{x,t}(h)$ from a Pareto distribution with lower bound $f_{x\ \min}$ and shape parameter $\varkappa > \theta - 1$. The cumulative density function is $\Gamma = 1 - \left(\frac{f_{x,t}}{f_{x\ \min}}\right)^{-\varkappa}$. The firm will then decide to export whenever the profits from doing so are higher than the export cost. The cut-off exporting firm, i.e. the last firm with export costs low enough to earn profits, is determined by the export zero-profit condition

$$\overline{d}_{X,t}(h) = \left(\frac{\varepsilon p^*_{X,t}(h)}{P_t} - \frac{W_t(1+\tau)}{P_t Z_t}\right) y^*_{X,t}(h) = f_{x,t}(h)\frac{P_{f,t}}{P_t} \tag{19}$$

The share of exporters is thus given by

$$\frac{N_{X,t}}{N_t} = \left[1 - \left(\frac{\overline{d}_{X,t}}{f_{x\ \min}}\right)^{-\varkappa}\right] \tag{20}$$

The share of exporters is an increasing function of the profit threshold: all firms with profits higher than the threshold will serve foreign markets. For the property of the Pareto distribution, a small fraction of firms operating in domestic markets will decide to export after a large rise in export profits (or a large fall in export costs).

Firms are monopolistic competitors. In the domestic market, a firm h faces the following demand:

$$y_D(h) = C_{D,t}(h) + \left(\frac{p_{D,t}(h)}{P_t}\right)^{-\theta} \sigma \left(\frac{P_{D,t}}{P_{X,t}}\right)^{\sigma-1} (f_{e,t}N_{e,t} + f_{x,t}N_{X,t}) \tag{21}$$

where the first addend is demand for consumption purposes and the second addend is demand for investment purposes. Export demand is given by a similar expression

$$y_X(h) = C^*_{X,t}(h) + \left(\frac{p^*_{X,t}(h)}{P^*_t}\right)^{-\theta} (1-\sigma) \left(\frac{P^*_{D,t}}{P^*_{X,t}}\right)^{-\sigma} \left(f^*_{e,t}N^*_{e,t} + f^*_{x,t}N^*_{X,t}\right) \tag{22}$$

We assume staggered prices à la Calvo (1983). In each period a firm can set a new price with a fixed probability $1-\alpha$ which is the same for all firms, both incumbents and new entrants, and is independent of the time elapsed since the last price change. In every period there is thus a share α of firms whose prices are pre-determined. In a symmetric equilibrium, pre-determined prices at a given point in time coincide with the average price chosen by firms active in the previous period.[14] The assumption that new entrants behave like incumbent firms is without loss of generality: allowing entrants to make their first price-setting decision in an optimal way would have only second order effects. It might have major consequences in a setting where firms face costs of price adjustment as it would introduce heterogeneity in price levels across cohorts of firms entered at different points in time (see Bilbiie et al., 2007). Explaining endogenous changes in nominal rigidity is behind the scope of this paper.

Each firm sets the price for its own products so as to maximize the present discounted value of future profits, taking into account demand in domestic (21) and in foreign markets (22) as well as the probability that she might not be able to change

[14] The average price for, say, domestic goods P_D is given by

$$(P_{D,t})^{1-\theta} = \frac{(P_{D,t-1})^{1-\theta}}{N_{t-1}}$$

and similarly for other price indexes. These properties are used in deriving the Calvo state equations below.

the price in the future. Optimal pricing gives

$$p_{D,t}(h)=\frac{\theta}{\theta-1}\frac{E_t\sum_{k=0}^{\infty}\left(\alpha\beta(1-\delta)\right)^k\frac{W_{t+k}}{Z_{t+k}}\frac{y_{t+k}(h)}{P_{t+k}C_{t+k}^{-\rho}}}{E_t\sum_{k=0}^{\infty}\left(\alpha\beta(1-\delta)\right)^k\frac{y_{t+k}(h)}{P_{t+k}C_{t+k}^{-\rho}}} \tag{23}$$

where $y_{t+k}(h)=y_{D,t+k}(h)+y_{X,t+k}(h)$.

Clearly, when $\alpha=0$ optimal pricing implies a constant markup $\theta/\theta-1$ on marginal costs at all dates. Otherwise, markpus are time-varying. The producer price index, PPI is given by

$$(P_{D,t})^{1-\theta}=\alpha\frac{N_t}{N_{t-1}}(P_{D,t-1})^{1-\theta}+(1-\alpha)N_t(p_{D,t}(h))^{1-\theta} \tag{24}$$

Note that an increase in the number of producers reduces the PPI. This is a consequence of love for variety: an increase in the range of available varieties implies an increase in the value of consumption per unit of expenditure. Producer prices must therefore fall.

Similarly, the price index for imported goods is

$$(P_{X,t})^{1-\theta}=\alpha\frac{N_{X,t}^*}{N_{X,t-1}^*}(P_{X,t-1})^{1-\theta}+(1-\alpha)N_{X,t}^*(p_{X,t}(f))^{1-\theta}$$

3.3. *Equilibrium and aggregate accounting*

Assuming symmetry in asset holdings in each economy (so that, $s_t=s_{t-1}$ and $s_t^*=s_{t-1}^*$), and defining real GDP as $Y_t\equiv\int_0^{N_t}\frac{p_{D,t}(h)}{P_{D,t}}y_t(h)\,dh$ in the Home economy and $Y_t^*\equiv\int_0^{N_t^*}\frac{p_{D,t}^*(f)}{P_{D,t}^*}y_t(f)\,df$ in the Foreign economy, a competitive equilibrium is defined as a sequence of quantities

$$\{Q_t\}_{t=0}^{\infty}=\left\{Y_t,Y_t^*,C_t,C_t^*,L_t,L_t^*,N_{e,t},N_{e,t}^*,N_t,N_t^*,N_{x,t},N_{x,t}^*,d_t,d_t^*,B_t,B_t^*,B_{*t},B_{*t}^*,\right\}_{t=0}^{\infty}$$

where B_{*t},B_{*t}^* denote foreign holdings of home and foreign bonds, respectively, and a sequence of real prices

$$\{P_t\}_{t=0}^{\infty}=\left\{\frac{p_{D,t}}{P_{D,t}},\frac{p_{D,t}^*}{P_{D,t}^*},\frac{p_{X,t}}{P_{X,t}},\frac{p_{X,t}^*}{P_{X,t}^*},\frac{W_t}{P_t},\frac{W_t^*}{P_t^*},\nu_t,\nu_t^*,q_t,ToT_t\right\}_{t=0}^{\infty}$$

such that, for a given sequence of shocks $\{Z_t,Z_t^*,T_t\}_{t=0}^{\infty}$, and conditional on given monetary policies in the two economies:

(1) for a given $\{P_t\}_{t=0}^{\infty}$, the sequence $\{Q_t\}_{t=0}^{\infty}$ satisfies first order conditions of domestic and foreign households and maximizes domestic and foreign firms' dividends;

(2) for a given $\{Q_t\}_{t=0}^{\infty}$, the sequence $\{P_t\}_{t=0}^{\infty}$ guarantees the equilibrium of goods markets:

$$\begin{aligned}Y_t&=\gamma C_t+\sigma(N_{e,t}f_{e,t}+N_{x,t}f_{x,t})+q_t\left[(1-\gamma)C_t^*+(1-\sigma)\left(f_{e,t}^*N_{e,t}^*+f_{x,t}^*N_{x,t}^*\right)\right]\\ Y_t^*&=\gamma C_t^*+\sigma\left(N_{e,t}^*f_{e,t}^*+N_{x,t}^*f_{x,t}^*\right)-q_t\left[(1-\gamma)C_t+(1-\sigma)(N_{e,t}f_{e,t}+N_{x,t}f_{x,t})\right]\end{aligned} \tag{25}$$

the equilibrium of labor markets

$$\begin{aligned}L_t&\geq\int_0^{N_t}\frac{y_t(h)}{Z_t}\,dh\\ L_t^*&\geq\int_0^{N_t^*}\frac{y_t(f)}{Z_t^*}\,df\end{aligned} \tag{26}$$

and the equilibrium of financial markets

$$\begin{aligned}B_t+B_{*,t}&=0\\ B_t^*+B_{*,t}^*&=0\end{aligned}$$

The net foreign asset position of the Home economy in Home currency is $B_t^{net}=B_t-\varepsilon_tB_t^*$. Normalizing initial financial wealth to zero in both economies, net foreign assets satisfy the aggregate accounting equations

$$\begin{aligned}Y_t-C_t-N_{e,t}v_t&=\frac{B_t^{net}}{P_t}\\ Y_t^*-C_t^*-N_{e,t}^*v_t^*&=-\frac{B_t^{net}}{\varepsilon_tP_t^*}\end{aligned} \tag{27}$$

The equilibrium defined above is conditional on the monetary policy in place in the world economy, which in turn determines the dynamics of the nominal exchange rate. The monetary instrument is the one-period risk-free nominal interest rate, i_t and i_t^* in, respectively, the Home and the Foreign economy. Monetary policy in both countries belongs to the class of feedback rules.

We will consider fixed and floating regimes in turn while overlooking the transition from one regime to the other.[15] Fixed regimes are modeled as hard pegs to the Foreign currency. In any fixed regime, monetary union or hard peg, UIP requires interest rate equalization at all dates. In unilateral pegs, the nominal interest rate is set by the leader country (the Foreign country in our simulations). In a monetary union, the interest rate is set by a supra-national monetary authority on the basis of union-wide targets. We have checked that considering a monetary union instead of a hard peg has no major consequences for our analysis. In floating regimes, the central banks in the two economies set nominal interest rates in an uncoordinated way and let the dynamics of the nominal exchange rate reflect changes in the interest differential across countries.

4. The log-linear model

The model is log-linearized around a symmetric steady where shocks are muted at all dates. This section discusses the main linearized equations while Appendix A contains the steady state and the full log-linearization.

4.1. Demand block

The aggregate demand block is derived from a log-linear approximation to Home and Foreign first order conditions with respect to consumption, bonds and shares. Inter-temporal optimization requires that the marginal rate of substitution between current and one-period ahead consumption equalizes the real return on nominal assets, both bonds and shares. A first set of Euler equations, one for each country, will therefore describe the dynamic link between current and expected one-period ahead consumption and relate it to the risk-free return in units of consumption. A second set of Euler equations, again one for each country, will relate the inter-temporal profile of consumption to the real return on shares. The real value of the firm, equal to the entry cost in equilibrium, is the forward solution to the Euler equations on shares.

The bond Euler equation in the Home country is

$$E_t\widehat{C}_{t+1} = \widehat{C}_t + \frac{1}{\rho}\left(\widehat{i}_t - E_t\pi^C_{t+1}\right) \tag{28}$$

where a hat over a variable denotes the log-deviation from the steady state and $\pi^C_{t+1} = \ln\frac{P_{t+1}}{P_t} - 1$. An increase in the real interest rate raises the return on bonds, making it more attractive to postpone consumption in the future.

The Euler on shares is

$$E_t\widehat{C}_{t+1} = \widehat{C}_t + \widehat{\nu}_t + \frac{1}{\rho}E_t\left(\frac{i+\delta}{1+i}\widehat{d}_{t+1} - \frac{1-\delta}{1+i}\widehat{\nu}_{t+1}\right)$$

Risk-sharing implies

$$\widehat{q}_t = \rho(\widehat{C}_t - \widehat{C}^*_t)$$

where the real exchange rate is given by

$$\widehat{q}_t = \widehat{q}_{t-1} + \Delta\widehat{\varepsilon}_t + (1-\gamma)\widehat{ToT}_t \tag{29}$$

Finally, UIP links expected exchange rate changes to the interest rate differential

$$E_t\Delta\widehat{\varepsilon}_{t+1} = \widehat{i}_t - \widehat{i}^*_t \tag{30}$$

4.2. Supply block

The supply block is derived from a log-linear approximation to the pricing and entry decisions of firms together with labor supply.

First, define the real price of domestic and imported varieties $\widehat{\rho}_{D,t} = \ln p_{D,t}(h)/P_{D,t}$ and $\widehat{\rho}_{X,t} = \ln p_{X,t}(f)/P_{X,t}$ respectively. Using the Calvo state equation (24), these prices are

$$\begin{aligned}\widehat{\rho}_{D,t} &= \frac{\alpha}{1-\alpha}\pi^D_t + \frac{1}{(1-\alpha)(\theta-1)}\widehat{N}_t - \frac{\alpha}{(1-\alpha)(\theta-1)}\widehat{N}_{t-1}\\ \widehat{\rho}_{X,t} &= \frac{\alpha}{1-\alpha}\pi^X_t + \frac{1}{(1-\alpha)(\theta-1)}\widehat{N}^*_{X,t} - \frac{\alpha}{(1-\alpha)(\theta-1)}\widehat{N}^*_{X,t-1}\end{aligned} \tag{31}$$

where $\pi^D_t = \ln(P_{D,t+1})/(P_{D,t}) - 1$ and $\pi^X_t = \ln(P_{X,t+1})/(P_{X,t}) - 1$. With $\alpha = 0$, an increase in the number of producers raises real

[15] The analysis of the implications of exchange rate crises for business formation is left to future research.

prices (the so-called variety effect) and the more so the lower the elasticity of substitution θ. This effect is dampened with $\alpha > 0$.

Using optimal pricing (23) in the expression for $\widehat{\rho}_{D,t}$ and re-arranging yields the Phillips curve

$$\pi_t^D = \frac{(1-\alpha\beta(1-\delta))(1-\alpha)}{\alpha}\left(\widehat{W}_t - Z_t\right) + \beta(1-\delta)E_t\pi_{t+1}^D + \frac{\beta(1-\delta)}{\theta-1}E_t\widehat{N}_{t+1} - \frac{1+\alpha\beta(1-\delta)}{\theta-1}\widehat{N}_t + \frac{1}{\theta-1}\widehat{N}_{t-1} \quad (32)$$

Imported inflation follows directly from the assumption on foreign currency pricing:

$$\pi_t^X = \eta\widehat{\varepsilon}_t + \frac{1}{\theta-1}\left(\widehat{N}_{X,t}^* - \widehat{N}_{X,t-1}^*\right) + \pi_t^{*D}$$

Second, a log-linear approximation to the number of entrants is obtained from the current account equation (27) as a function of output minus absorption and net foreign assets

$$\widehat{N}_{e,t} = \frac{\theta(1-\beta(1-\delta))}{\beta\delta}\widehat{Y}_t + \left(1 - \frac{\theta(1-\beta(1-\delta))}{\beta\delta}\right)\widehat{C}_t - \widehat{\nu}_t - \frac{(1-\delta)}{\delta}\widehat{nfa}_t \quad (33)$$

where $\widehat{nfa}_t = \widehat{b}_t - 1/\beta\widehat{b}_{t-1}$ and $b_t = (B_t^{net}/Y_tP_t)$. The aggregate constraint implies a trade-off between investments in new varieties and consumption (the coefficient on C is negative). The law of motion of firms is

$$\widehat{N}_t = (1-\delta)\widehat{N}_{t-1} + \delta\widehat{N}_{e,t-1} \quad (34)$$

From (20) and (19), the dynamics of exporting firms is given by

$$\widehat{N}_{X,t} = \widehat{N}_t + \varkappa\left(\widehat{\mu}_{X,t} + \widehat{y}_{X,t}^*\right) \quad (35)$$

where $\widehat{\mu}_{X,t}$ are export profits. The first addend in the equation above represents trade of new products. For a given share of exporters, new goods will be exported as long as new products are created in the economy. The second addend reflects trade of previously non traded goods, i.e. changes in the export threshold. An increase in export margins $\widehat{\mu}_{X,t}$ and/or in export demand $\widehat{y}_{X,t}^*$ will boost export profits and raise the share of producers who will be able to cover export costs.

Finally, labor supply is

$$\widehat{L}_t = -\rho\varphi\widehat{C}_t + \varphi\left(\widehat{W}_t - \pi_t^C\right) \quad (36)$$

4.3. Exchange rate regimes

We consider fixed and floating exchange rate regimes. The fixed regime is a unilateral (hard) peg to the Foreign currency with a fixed exchange rate at all dates. It is implemented by the interest rule $\widehat{i}_t = \widehat{i}_t^* - \varsigma\widehat{\varepsilon}_t$ with $\varsigma > 0$. The exchange rate target (normalized to zero) ensures determinacy.[16]

In the floating regime, monetary policy in the two economies follows a symmetric Taylor rule with interest rate smoothing, $\widehat{i}_t = \phi\widehat{i}_{t-1} + \phi_\pi\pi_t^C + \phi_y\,\widehat{y}_t$ in the home country and $\widehat{i}_t^* = \phi\widehat{i}_{t-1}^* + \phi_\pi\pi_t^{*C} + \phi_y\,\widehat{y}_t^*$ in the foreign economy. The Taylor principle, $\phi_\pi > 1$, ensures determinacy (Taylor, 1993).

4.4. Simulations

The model is simulated using second-order perturbation methods as in Schmitt-Grohe and Uribe (2004).[17] We first consider shocks to productivity and the terms of trade in flexible regimes, with the purpose of illustrating the transmission mechanism at work in the model. Then, we focus on terms of trade shocks and compare the responses in fixed and floating regimes, as is done in the empirical exercise.

4.5. Calibration

For consistence with the empirical analysis, country H represents the average economy in the sample of developed economies examined while F is the rest of the world. The dimension of country H in the world economy is $\gamma = 0.6$, as is the share of world output represented in our sample. Note that in the model $1-\gamma$ measures the share of imports in consumption while $1-\sigma$ is the share of imports in investments. These shares may in principle affect the dynamics of the model through their impact on entry costs. Since there is no evidence for all countries in our sample, we arbitrarily set $\sigma = 0.4$ in the baseline calibration, and let it vary between 0.2 and 0.8 with no major consequences on the results.

[16] For robustness purposes, we have considered a monetary union in which the nominal interest rate is set according to a union-wide Taylor rule $\widehat{i}_t = \phi\widehat{i}_{t-1} + \phi_\pi\overline{\pi}_t^C + \phi_y\widehat{\overline{y}}_t$ where $\overline{\pi}_t^C = (\pi_t^C)^\gamma(\pi_t^{*C})^{1-\gamma}$ and $\overline{y}_t^C = (y_t)^\gamma(y_t^*)^{1-\gamma}$ are union-wide targets. This has no remarkable implications for the qualitative properties of the impulse responses.

[17] Simulations are made with Dynare. The algorithm used to compute a quadratic approximation of the decision rules is described in Collard and Juillard (2001).

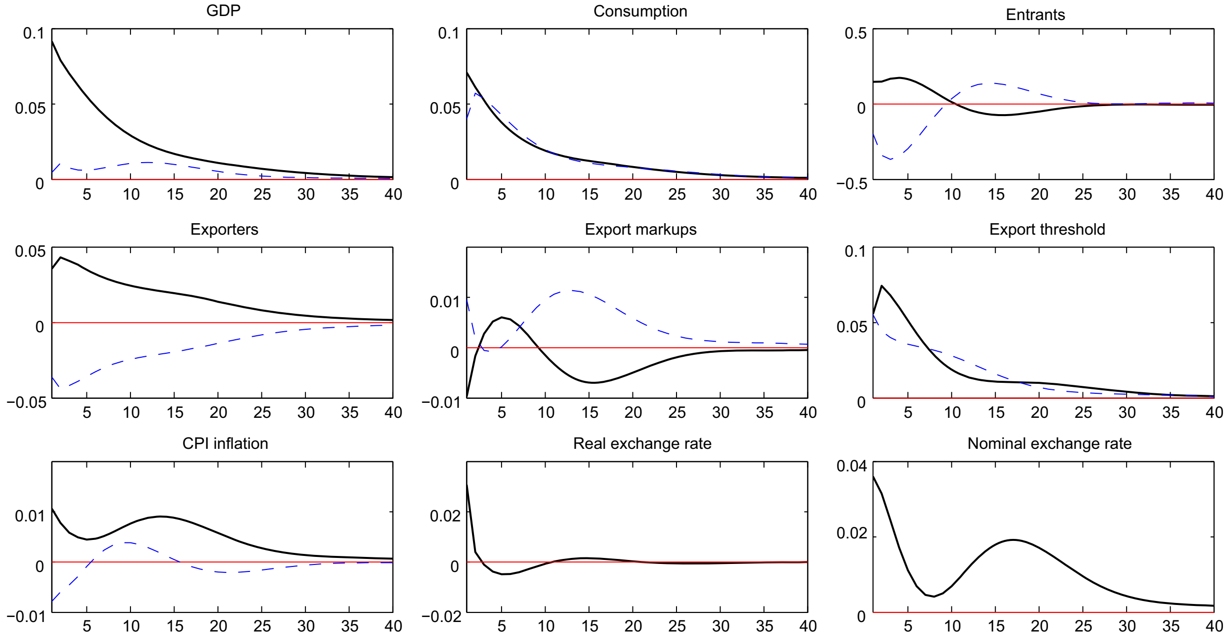

Fig. 3. Responses to a one standard deviation rise in Home productivity in the Home country (solid lines) and in the Foreign country (dashed lines). (For interpretation of the references to color in this figure, the reader is referred to the web version of this paper.)

Periods are interpreted as years. As is usual in business cycle studies, the interest rate is $i=0.04$ and $\beta=0.96$. The probability of exit is $\delta=0.10$ as in Bilbiie et al. (2012). The rate of firm disappearance matches the rate of job destruction per year in US data. In addition to favoring comparison with previous studies, the choice is motivated by scant evidence for many countries in our sample. For analogous reasons, the parametrization of consumers' preferences is based on Bilbiie et al. (2012): the inter-temporal elasticity of substitution is $\rho=1$, the Frisch elasticity is $\varphi=4$, the disutility of labour is normalized so that the steady state level of employment is equal to one and the elasticity of substitution across varieties is $\theta=3.8$. The choice of θ implies markups as high as 35 percent. Many studies consider a higher θ and a lower markup more adequate for aggregate data. Rotemberg and Woodford (1999), for instance, document a markup of about 18 percent in US data. We have checked that using $\theta=7.8$ so as to reproduce a steady state markup of 18 percent does not affect the qualitative properties of the impulse responses.

Four parameters characterize the whole process of business formation and export selection in our setup. The entry cost f_e and the level parameter of the distribution of export costs $f_{x\ \min}$ have no consequences on the dynamics of the model and can be normalized to unity without loss of generality. The shape parameter is chosen to reproduce the average standard deviation of the extensive margin in our sample, implying $\varkappa=2.8$.[18] The iceberg cost does not affect any of the impulse responses, yet its value cannot be arbitrarily set. It is tied to the export share through the zero profit condition (19). Given an export share equal to 0.27 as in the average economy in our sample, this implies a value of $\tau=0.49$. This is slightly higher than the value $\tau=0.3$ considered in Ghironi and Mélitz (2005), yet well in the range of values $(0.3, 0.75)$ considered in Corsetti et al. (2013).

Using quarterly data for major developed economies, Galì et al. (2001) document a degree of nominal rigidity in the range between 0.407 and 0.771 per year. We take the middle point from these estimates and set $\alpha=0.59$, implying an average duration of nominal contracts of about 7 months. The degree of exchange rate pass-through varies widely across countries and sectors. Moreover, it seems to have declined far below unity in recent times. We set $\eta=0.6$ in line with the average degree of long-run pass-through documented by Campa and Goldberg (2005) in a sample of developed economies comprising most of the countries in our dataset.

The parameters of the Taylor rule draw on Bilbiee et al. (2007), $\phi_i=0.8$, $\phi_y=0$ and $\phi_\pi=0.3$. They imply a long-run response to inflation equal to 1.5 and no role for output stabilization. In an appendix, available upon request, we have considered positive values for the coefficient on output. Not surprisingly, we find that output stabilization comes at a cost in terms of higher volatility of nominal variables and consumption. It has no major consequences for the behavior of export margins.

The parameters of the exogenous productivity process, $Z_t=\rho_Z Z_{t-1}+\epsilon_{Z,t}$, are an annualized version of those in King and Rebelo (1999), i.e. $\rho_z=0.815$ and $\sigma_z=0.013$. Since productivity shocks are considered essentially for illustrative purposes,

[18] The shape parameter is such that $\sqrt{\frac{\varkappa(f_{x\ \min})^2}{(\varkappa-1)^2(\varkappa-2)}}=6.5$.

this provides a reasonable benchmark. The parameters of the exogenous process of the terms of trade $T_t = \rho_T T_{t-1} + \epsilon_{T,t}$, match the average persistence and volatility of the terms of trade in our sample, implying $\rho_T = 0.85$ and $\sigma_T = 0.021$.

4.6. *International transmission*

Fig. 3 shows impulse response functions to a one-standard-deviation shock to Home productivity. The vertical axis shows percentage deviations from the steady state (a value of, say, 0.01 denotes a 1 percent deviation) and the horizontal axis shows the number of periods after the shock. Solid lines display responses of home variables while dashed lines display responses of foreign variables.

First consider home responses (solid black lines). The productivity rise creates a favorable business environment which attracts entry of new firms and creation of new products, in line with what found in previous studies. In addition, the number of exporting firms (the extensive margin) also rises. Availability of new traded goods is the result of creation of brand new products (rise in N) as well as trade of previously non-traded goods (rise in the export threshold). In principle, the productivity shock may have an ambiguous effect on the export threshold. It makes home products more competitive in global markets, thereby increasing export profits (not shown in Fig. 3). This in turn makes it easier for domestic firms to cover export costs and become exporters. On the other side, however, export markups fall. Since export markups depend essentially on η and θ, we have experimented with the whole range of admissible parameters, i.e. $\eta \in (0,1)$ and $\theta \in (3,10)$. The first effect always dominates.

Now focus on foreign responses (dashed blue lines). The productivity rise spreads its benefits abroad through the real appreciation of the foreign currency (rise in q_t) and the improvement in the foreign terms of trade (fall in ToT_t). Interestingly, the model captures positive comovements of output and consumption across countries as found in the data. As stressed in Cavallari (2013), entry may help overcome the well-known difficulty of standard (fixed variety) business cycle models in this regard (see Backus et al., 1992). Moreover, foreign consumption stays below home consumption in the first years of the transition, implying less than perfect cross-correlation as in the data. In our setup, real exchange rate movements allow to partly absorb the effects of the shock. The real appreciation of the foreign currency has a negative impact on foreign entry. Despite the favorable external environment, prospective profits fall below entry costs as long as households substitute more expensive domestic products with imports. For a similar reason, the number of foreign exporters also falls.

Fig. 4 displays responses of home (solid black lines) and foreign variables (dashed blue lines) to a one-standard deviation rise in the Home terms of trade. The appreciation boosts GDP and consumption at home while having the opposite effect in the foreign country. In contrast to productivity shocks, which spread their effects symmetrically in the world economy, terms of trade shocks imply a redistribution of wealth across countries. Interestingly, entry of new firms can partly offset external spillovers. Expenditure substitution, in fact, discourages the creation of new products in the country hit by a positive shock (the home country in our simulations) relative to the trading partner ($N_{e,t}/N^*_{e,t}$ and $N_{X,t}/N^*_{X,t}$ both fall).

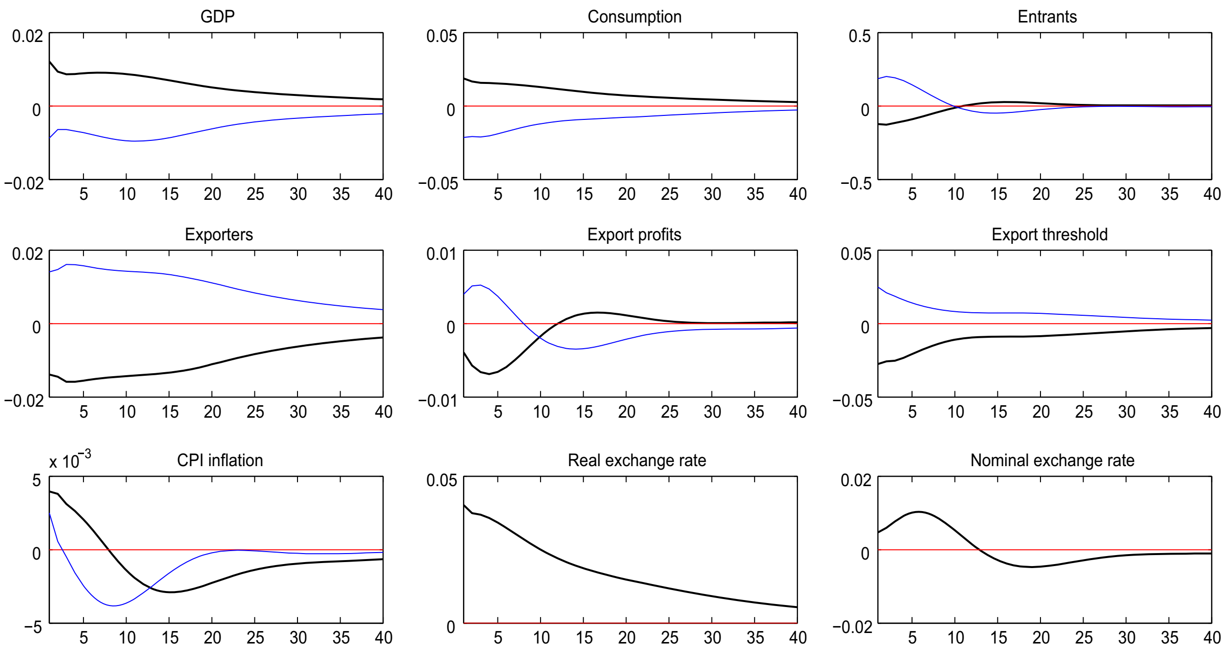

Fig. 4. Responses to a one standard deviation rise in home terms of trade in the Home country (solid black lines) and in the Foreign country (dashed blue lines). (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)

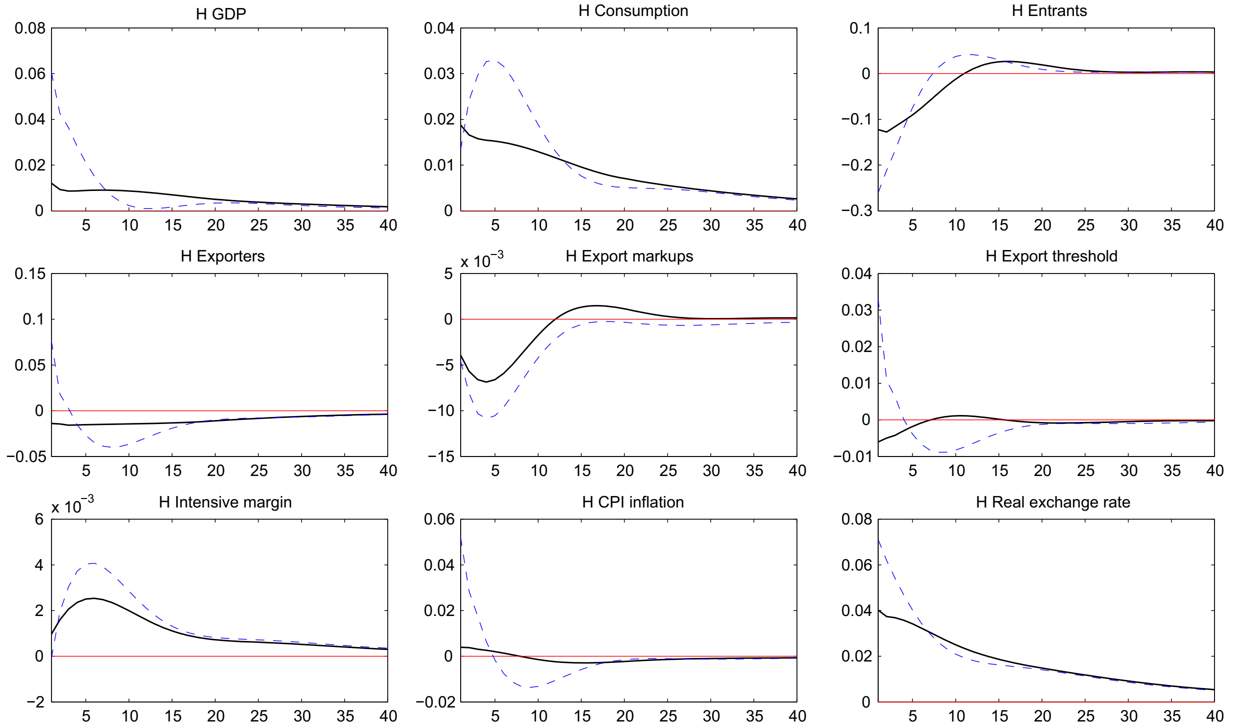

Fig. 5. Home impulse responses to a one standard deviation increase in home terms of trade with flexible exchange rates (solid line) and with fixed rates (dashed line).

4.7. Pegs versus floating regimes

We now focus on terms of trade shocks in fixed and floating regimes as is done in the empirical exercise. Fig. 5 shows impulse responses of Home variables to a one-standard deviation increase in home terms of trade. Impulse responses are displayed under flexible exchange rates (solid line) and with fixed exchange rates (dashed line).

A positive shock to the terms of trade increases wealth, thereby boosting GDP and consumption. It also makes home products more expensive in global markets and switches world expenditure towards foreign products. In our setup with entry, these effects may alter the attractiveness of investing in production capacity (intensive margin) compared to investing in new businesses (extensive margin). As a matter of fact, expected profits from creation of new varieties fall below entry costs, discouraging the start up of new businesses (N_e falls). Incumbents will eventually accommodate market demand by increasing their size. In export markets, the effect is a priori ambiguous. On the one side, the drop in the range of varieties produced for the domestic market (drop in N, not shown in Fig. 5) reduces also the range of varieties that will be exported (recall (35)). On the other side, however, a larger share of domestic producers may find it profitable to export when export prices rise. In Fig. 5, which one of these opposing effects prevails depends on the exchange rate regime. The number of exporters increases in fixed regimes. Our clue is that a larger number of potential exporters are induced to trade previously non-traded goods and take advantage of higher export prices so long as there is no exchange rate risk over the whole investment horizon. In floating regimes, on the contrary, exchange rate variability reduces expected export profits.

All other responses are qualitatively similar in fixed and floating regimes, except for the dynamics of consumption. In fixed regimes, consumption has a hump-shape that is absent with flexible rates. The hump reflects the trade-off implied by sticky prices: with a fixed exchange rate, the real depreciation of the home currency, the increase in q_t, must be entirely brought about by cross-country inflation differentials. These, in turn, are slow in the early part of the transition, when prices are sticky. In floating regimes, on the contrary, nominal exchange rate depreciation (not shown in Fig. 5) allows to partly offset the effect of the shock. With a smoother real exchange rate, consumption converges monotonically to the steady state.

Quantitatively, responses are higher with fixed exchange rates than with floating rates. The reason is once again shock absorption in flexible regimes. The nominal depreciation of the home currency allows to partly counteract the effects of the appreciation, thereby dampening adjustment in terms of quantity. We stress that trade adjusts mainly at the extensive margin, and particularly so in fixed regimes. In these regimes, the number of exporters rises by almost 5% at impact while the peak increase in the intensive margin is around 0.7%. In floating regimes, the number of exporting firms falls by around 2% and the intensive margin increases by less than 0.2%.

Previous studies have provided evidence of asymmetry in the propagation of terms of trade shocks across countries, with negative shocks found to be more important than positive shocks in explaining output volatility. In a sample of 75

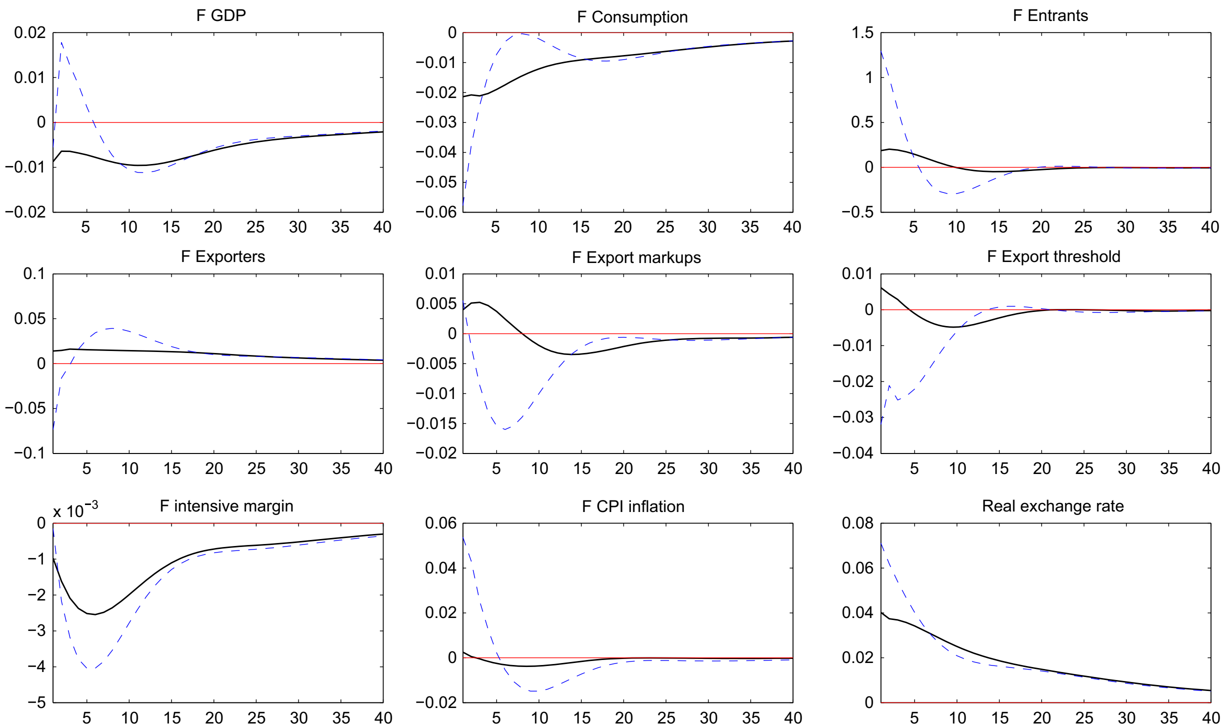

Fig. 6. Foreign impulse responses to a one standard deviation increase in home terms of trade with flexible exchange rates (solid line) and with fixed rates (dashed line).

developing countries, Broda (2004) finds that differences in the response of output to terms of trade shocks across exchange rate regimes are mainly driven by negative shocks (see also Levy-Yeyati and Sturzenegger, 2003 for a sample of 183 developed and developing economies). In order to address asymmetry, consider the impact of the shock in the foreign economy. Fig. 6 shows responses of foreign variables to a one standard deviation rise in home terms of trade. As before, solid lines are responses with floating rates and dashed lines are responses with fixed rates.

The terms of trade depreciation reduces consumption and GDP in all periods, except for a transitory output spike in fixed regimes. The spike reflects an increase in investments in new businesses (recall that investments are entirely given by start-ups) which is well above the fall in consumption. Entry of new firms increases in both fixed and floating regimes. As before, and for similar motives, the effect is stronger in fixed regimes.

In our model, asymmetry arises from endogenous changes in the range of varieties available at home and abroad. A positive shock (home appreciation) is associated with a fall in $N_{e,t}/N^*_{e,t}$. The reallocation of start-up investment towards the foreign country helps to dampen negative output spillovers in the foreign economy. On the other side, the home appreciation leads to an increase in $N_{X,t}/N^*_{X,t}$, i.e. more varieties available to foreign household. This dampens the fall in foreign consumption. Contrary to the Friedman's hypothesis, our model suggests that fixed exchange rates may dampen output fluctuations in the country hit by a negative shock.

5. Conclusions

This study has addressed the role of floating exchange rates as shock absorber when adjustment involves trade of previously traded goods (intensive margin) as well as trade of new goods and previously non-traded goods (extensive margin). As motivation, the paper has used a panel VAR model to study the dynamics of trade margins in response to terms of trade shocks. In a sample of 23 developed economies, we find a positive relationship between innovations in the terms of trade and extensive margins, while the effect on intensive margins is negligible. In addition, the average response of the extensive margin is almost three times as high among peggers than among floaters. The average cumulated output effect is twice as large in the sample of peggers than in the sample of floaters. Adjustment to real shocks appears to occur mainly at the extensive margin and particularly so in fixed regimes. This in turn amplifies output fluctuations, in line with the Friedman's hypothesis.

We then propose a model with firm entry and endogenous selection of exporters that generates dynamics consistent with the empirical facts outlined above. In the model, a positive shock to the terms of trade of a country (an appreciation) switches world expenditure towards foreign products and induces a reallocation of start-up investments in the foreign economy. The effects on trade of new products and previously non-traded goods is in principle ambiguous. The fall in the range of products available in domestic markets reduces the range of varieties that will be exported. However, a larger share of domestic producers may find it convenient to export when export prices increase. The overall effect is positive (and stronger) in fixed regimes.

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Appendix A

A.1. Steady state

The model is solved in log-deviation from a symmetric steady state equilibrium in which all shocks are muted and inflation is zero. For reasons of determinacy, we solve the steady state under the assumption of an exogenously given share of exporters equal to ψ. It is immediate to verify that symmetry implies $q=\varepsilon=ToT=1$. The steady state number of firms is obtained from the following expression:

$$\frac{(1-\beta(1-\delta))\theta N}{\beta(1-\delta)}=\left(\frac{\theta}{(\theta-1)}\right)^{1/\varphi}\left(\frac{\psi^{1/(\theta-1)}}{1+\tau}\right)^{2\varphi(1-\gamma)}N^{((\varphi-\theta)/(\theta-1))-\varphi\rho}\left(\frac{\theta(1-\beta(1-\delta))-\delta\beta}{\beta(1-\delta)}\right)^{-\varphi\rho}$$

Other variables are given by

$$i=\frac{1-\beta}{\beta},\quad \frac{P_D}{P_X}=\frac{\psi^{1/(\theta-1)}}{1+\tau},\quad v=\left(\frac{P_D}{P_X}\right)^{\sigma-\gamma},\quad d=\frac{(1-\beta(1-\delta))}{\beta(1-\delta)},\quad \mu=\frac{\theta}{(\theta-1)},\quad \frac{P_D(h)}{P_D}=N^{\frac{1}{\theta-1}}$$

$$C=\theta N\left[\frac{1-\beta(1-\delta)}{\beta(1-\delta)}-\frac{\delta}{\theta(1-\delta)}\right],\quad L=\theta\, dN^{(2-\theta)/(1-\theta)},\quad Y=\theta\, dN,\quad N_e=\frac{\delta}{(1-\delta)}N$$

A.2. Loglinear model

Loglinearized conditions for households are

$$E_t\widehat{C}_{t+1}=\widehat{C}_t+\frac{1}{\rho}\left(\widehat{i}_t-E_t\pi_{t+1}\right)$$
$$E_t\widehat{C}_{t+1}=\widehat{C}_t+\widehat{\nu}_t+\frac{1}{\rho}E_t\left(\frac{i+\delta}{1+i}d_{t+1}+\frac{1-\delta}{1+i}\widehat{\nu}_{t+1}\right)$$
$$E_t\widehat{C}^*_{t+1}=\widehat{C}^*_t+\widehat{\upsilon}^*_t+\frac{1}{\rho}E_t\left(\frac{i+\delta}{1+i}d^*_{t+1}+\frac{1-\delta}{1+i}\widehat{\nu}^*_{t+1}\right)$$
$$\widehat{L}_t=-\rho\varphi\widehat{C}_t+\varphi\left(\widehat{W}_t-\pi^C_t\right)$$
$$\widehat{L}^*_t=-\rho\varphi\widehat{C}^*_t+\varphi\left(\widehat{W}^*_t-\pi^{*C}_t\right)$$

Loglinearized conditions for firms are

$$\widehat{N}_t=(1-\delta)\widehat{N}_{t-1}+\delta\widehat{N}_{e,t-1}$$
$$\widehat{N}^*_t=(1-\delta)\widehat{N}^*_{t-1}+\delta\widehat{N}^*_{e,t-1}$$
$$\widehat{N}_{X,t}=\widehat{N}_t+\varkappa\left(\widehat{\mu}_{X,t}+\gamma(\pi^{*D}_t-\pi^{*X}_t)\right)$$
$$\widehat{N}^*_{Xt}=\widehat{N}^*_t+\varkappa\left(\widehat{\mu}^*_{X,t}+\gamma(\pi^D_t-\pi^X_t)\right)$$
$$\widehat{\mu}_t=\alpha\beta(1-\delta)\left(E_t\widehat{\rho}_{D,t+1}-\widehat{\rho}_{D,t}+E_t\pi^D_{t+1}\right)$$
$$\widehat{\mu}^*_t=\alpha\beta(1-\delta)\left(E_t\widehat{\rho}^*_{D,t+1}-\widehat{\rho}^*_{D,t}+E_t\pi^{*D}_{t+1}\right)$$
$$\widehat{\mu}_{X,t}=\alpha\beta(1-\delta)\left(E_t\widehat{\rho}^*_{X,t+1}-\widehat{\rho}^*_{X,t}+E_t\pi^{*X}_{t+1}\right)$$
$$\widehat{\mu}^*_{X,t}=\alpha\beta(1-\delta)\left(E_t\widehat{\rho}_{X,t+1}-\widehat{\rho}_{X,t}+E_t\pi^X_{t+1}\right)$$

$$\pi_t^D = \frac{(1-\alpha\beta(1-\delta))(1-\alpha)}{\alpha}\left(\widehat{W}_t - Z_t\right) + \beta(1-\delta)E_t\pi_{t+1}^D + \frac{\beta(1-\delta)}{\theta-1}E_t\widehat{N}_{t+1} - \frac{1+\alpha\beta(1-\delta)}{\theta-1}\widehat{N}_t + \frac{1}{\theta-1}\widehat{N}_{t-1}$$

$$\pi_t^{*D} = \frac{(1-\alpha\beta(1-\delta))(1-\alpha)}{\alpha}\left(\widehat{W}_t^* - Z_t^*\right) + \beta(1-\delta)E_t\pi_{t+1}^{*D} + \frac{\beta(1-\delta)}{\theta-1}E_t\widehat{N}_{t+1}^* - \frac{1+\alpha\beta(1-\delta)}{\theta-1}\widehat{N}_t^* + \frac{1}{\theta-1}\widehat{N}_{t-1}^*$$

Other log-linear equilibrium conditions are

$$\widehat{\rho}_{D,t} = \frac{\alpha}{1-\alpha}\pi_t^D + \frac{1}{(1-\alpha)(\theta-1)}\widehat{N}_t - \frac{\alpha}{(1-\alpha)(\theta-1)}\widehat{N}_{t-1}$$

$$\widehat{\rho}_{D,t}^* = \frac{\alpha}{1-\alpha}\pi_t^{*D} + \frac{1}{(1-\alpha)(\theta-1)}\widehat{N}_t^* - \frac{\alpha}{(1-\alpha)(\theta-1)}\widehat{N}_{t-1}^*$$

$$\widehat{\rho}_{X,t} = \frac{\alpha}{1-\alpha}\pi_t^X + \frac{1}{(1-\alpha)(\theta-1)}\widehat{N}_{X,t}^* - \frac{\alpha}{(1-\alpha)(\theta-1)}\widehat{N}_{X,t-1}^*$$

$$\widehat{\rho}_{X,t}^* = \frac{\alpha}{1-\alpha}\pi_t^{*X} + \frac{1}{(1-\alpha)(\theta-1)}\widehat{N}_{X,t} - \frac{\alpha}{(1-\alpha)(\theta-1)}\widehat{N}_{X,t-1}$$

$$\pi_t^X = \eta\widehat{\varepsilon}_t + \frac{1}{\theta-1}\left(\widehat{N}_{X,t}^* - \widehat{N}_{X,t-1}^*\right) + \pi_t^{*D}$$

$$\pi_t^{*X} = -\eta\widehat{\varepsilon}_t + \frac{1}{\theta-1}\left(\widehat{N}_{X,t} - \widehat{N}_{X,t-1}\right) + \pi_t^D$$

$$\pi_t^C = \gamma\pi_t^D + (1-\gamma)\pi_t^X$$

$$\pi_t^{*C} = \gamma\pi_t^{*D} + (1-\gamma)\pi_t^{*X}$$

$$\widehat{Y}_t = \gamma(1-\varrho)\widehat{C}_t + \varrho\sigma\widehat{N}_{e,t} + (1-\gamma)(1-\varrho)\left(\widehat{C}_t + \widehat{q}_t\right) + (1-\sigma)\varrho\left(\widehat{N}_{e,t}^* + \widehat{q}_t\right) + (1-\sigma)\varrho f_x\left(\widehat{N}_{X,t}^* + \widehat{q}_t\right)$$

$$\widehat{Y}_t^* = \gamma(1-\varrho)\widehat{C}_t^* + \varrho\sigma\widehat{N}_{e,t}^* + (1-\gamma)(1-\varrho)\left(\widehat{C}_t^* - \widehat{q}_t\right) + (1-\sigma)\varrho\left(\widehat{N}_{e,t} - \widehat{q}_t\right) + (1-\sigma)\varrho f_x\left(\widehat{N}_{X,t} - \widehat{q}_t\right)$$

$$\widehat{N}_{e,t} = \frac{\theta(1-\beta(1-\delta))}{\beta\delta}\widehat{Y}_t + \left(1 - \frac{\theta(1-\beta(1-\delta))}{\beta\delta}\right)\widehat{C}_t - \widehat{\nu}_t - \frac{(1-\delta)}{\delta}\widehat{nfa}_t$$

$$\widehat{N}_{e,t}^* = \frac{\theta(1-\beta(1-\delta))}{\beta\delta}\widehat{Y}_t^* + \left(1 - \frac{\theta(1-\beta(1-\delta))}{\beta\delta}\right)\widehat{C}_t^* - \widehat{\nu}_t^* + \frac{(1-\delta)}{\delta}\widehat{nfa}_t$$

$$\widehat{nfa}_t = \widehat{Y}_t - \left(1 - \frac{\beta\delta(1-\delta)}{\theta(1-\beta(1-\delta))}\right)\widehat{C}_t - \frac{\beta\delta(1-\delta)}{\theta(1-\beta(1-\delta))}\widehat{N}_{e,t} - \pi_t^C$$

$$E_t\Delta\widehat{\varepsilon}_{t+1} = \widehat{i}_t - \widehat{i}_t^*$$

$$\widehat{\nu}_t = (\sigma-\gamma)\left(\pi_t^D - \pi_t^X\right)$$

$$\widehat{\nu}_t^* = (\sigma-\gamma)\left(\pi_t^{*D} - \pi_t^{*X}\right)$$

$$\widehat{q}_t = \rho\left(\widehat{C}_t - \widehat{C}_t^*\right)$$

$$\widehat{q}_t = \widehat{q}_{t-1} + \Delta\widehat{\varepsilon}_t + (1-\gamma)\left(T_t + \left(\pi_t^{*X} - \pi_t^X\right)\right)$$

where $\varrho = (\delta\beta)/(\theta(1-\beta(1-\delta)))$.

The model is closed with the interest rate rules in the text.

Appendix B

B.1. Data

See Table B1.

Table B1
Data.

Original series	**Source**	**Data transformation**
Peggers and floaters nominal GDP	OECD.StatExtracts	Log difference after deflating with GDP deflator
Peggers and floaters GDP deflator	OECD.StatExtracts	None
Peggers and floaters export price index	IFS-IMF database	Used to calculate terms of trade
Peggers and floaters import price index	IFS-IMF database	Used to calculate terms of trade
Peggers and floaters trade margins	UN Comtrade database	None

B.2. *Peggers and floaters*

See Table B2.

Table B2
Data.

Peggers	Floaters
Belgium	Australia
Denmark	Canada
Finland	Czech Republic
France	Iceland (after 2001)
Germany	Japan
Iceland (before 2001)	Mexico
Italy	New Zealand
Luxembourg	Norway
Netherlands	South Korea
Portugal	Sweden
Spain	Switzerland
	United Kingdom
	United States

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