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ABSTRACT

This paper proposes a two-country monetary model with firm entry as a means for alleviating the comovement puzzles in international business cycle models. It shows that business formation can generate fluctuations in output, employment, investment and trade flows close to those in the data while at the same time providing positive international comovements. Simulations show that the presence of imported investment goods is essential for replicating these facts.

1. Introduction

This paper studies the international business cycle in a monetary model with firm entry. It shows that business formation can generate fluctuations in output, employment, investment and trade flows close to those in the data while at the same time providing positive international comovements. The capacity to capture these facts simultaneously overcomes well-known difficulties of standard international business cycle models in this regard. As first shown by Backus et al. (1992), these models typically imply very low or even negative cross-correlations (the comovement puzzle) and a correlation of output lower than that of employment, consumption and investment (the quantity anomaly). In addition, they fail to match the counter-cyclical behavior of net exports. Successive research has mostly relied on some form of market incompleteness as a means for alleviating these puzzles. This paper takes a different route by focusing on entry as an international transmission mechanism for business cycle shocks. It finds that a business cycle expansion in one country leads to the formation of new firms in the trading partner's market: firm entry indeed provides a channel for positive comovements.

I propose a two-country dynamic stochastic general equilibrium model with monopolistic competition where producers are subject to a sunk entry cost, a one-period production lag and to an exogenous exit shock. Investments are represented by entry of new firms. A key assumption in the model is that prior to entry investors must acquire a basket of domestic and foreign goods, so that entry costs have a non-negligible component of imports. Later in the paper, I discuss the implications of modeling entry costs as wages. The economy has complete financial markets and a fully specialized structure of production. Nominal rigidity is captured by a price-setting à la Calvo (1983). Monetary policy is represented in the standard form of a feedback rule as in the Neo-Wicksellian framework (Woodford (2003)) and the global nature of the monetary regime is captured by the interaction of interest rules followed by the monetary authorities in the two countries. I consider floating regimes under symmetric Taylor rules, with or without interest smoothing, and a regime where the exchange rate is fixed at all dates. In order to assess the role of sticky prices I also consider a flexible price equilibrium.

Simulations show that accounting for imports in entry costs is essential for matching the properties of the international business cycle in the data. The reason is the role of the terms of trade in creating new investment opportunities worldwide. In order to see why consider a positive productivity shock in the home country. In the face of the shock, the price of home-produced goods falls relative to the price of foreign-

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produced goods, deteriorating the home terms of trade. In the partner country (the low productivity economy) entry costs fall below the present discounted value of future profits (the value of the firm), thereby stimulating investments in new firms. A rise in the number of producers leads to an expansion in output and employment in both economies. This channel is obscured when entry costs comprise domestic goods only.

The paper belongs to a recent line of research stressing the role of firm dynamics in the business cycle.[1] Its theoretical contribution is to provide a monetary model with firm entry as a means for reconciling international business cycle models with the evidence on comovements. The map of the paper in the literature, however, can be read along more than one dimension. A first dimension concerns the specification of the entry costs. As is now well understood, modeling these costs as wages has counterfactual implications in monetary models. For example, a monetary expansion leads to a fall in business formation at odds with the empirical evidence.[2] For this reason, Bergin and Corsetti (2008) have proposed to model entry costs as product prices. In an open economy, the debate extends to the composition of entry costs in terms of domestic and imported goods. An important contribution of this paper is to clarify that varying the import content of entry costs affects the transmission of business cycle shocks among interdependent economies. In the model, the presence of imported investment goods is essential for reproducing the positive comovements in the data.

The other dimension relates to entry costs as a form of investment in production capacity. As first shown by Bergin and Corsetti (2008), firm entry alters the transmission of monetary policy shocks, acting much like investments at the intensive margin in standard (fixed-variety) models. In a closed economy they find that the presence of the extensive margin amplifies the real effects of monetary policy. A fall in the real interest rate, in fact, raises the expected discounted profits from creating a new firm above the entry cost (i.e., the real price of investment drops), thus encouraging business formation. In open economies, a similar mechanism works through movements in the terms of trade. This is true in most international business cycle models, but analyses explicitly stressing this point, as is done in this paper, are rare.[3] In my model, changes in the terms of trade affect the relative price of investment, in the particular form of "investment to setup a new firm". Business formation, in turn, amplifies the international transmission of shocks, thereby alleviating the comovement puzzles.

A number of authors have analyzed the open economy implications of firm entry. Among early attempts, Cook (2002) finds positive comovements in a real model with sequential entry, time-varying capital utilization and incomplete financial markets. In his model the transmission mechanism is based on a pro-competitive effect of entry that is absent in my setup: business formation causes a decline in markups that leads to an expansion in output, employment and investment in both economies. More recent contributions have mainly focused on explaining the dynamics of trade margins and foreign investments. In these papers, monetary policy is either overlooked (as for example in Ghironi and Melitz (2005) and Helpman et al. (2004)) or considered as an exogenous source of business cycle variability (as in Russ (2007) and Cavallari (2007, 2010)). Yet the evidence discussed above suggests that monetary policy may play a relevant role in a firm's decision whether to start-up a new production unit.

Open economy models combining endogenous monetary policy and firm entry are surprisingly sparse. Most closely related to my work are the papers by Auray et al. (2012) and Auray and Eyquem (2011). The former focuses on a transmission mechanism that may be considered complementary to the one analyzed here. It emphasizes the role of asset prices in a context of complete financial integration and labor entry costs. The free entry condition in the model, equalizing the value of the firm to labor marginal costs, provides a direct link between asset prices and inflation that is absent in my setup. Entry costs as wages, however, imply a positive relation between business formation and interest rate shocks at odds with the data. The latter paper considers incomplete financial markets with given asset prices. In this setup, firm value is tied to an exogenous entry cost and shocks are transmitted through changes in the real return on assets. A rise in the real return on equity, as after a positive productivity shock, is brought about by an increase in the expected dividends from investing in new firms. In the low productivity economy, this requires a fall in business formation in contrast to what found in the data.

The remainder of the paper is organized as follows. Section 2 models a two-country world economy and Section 3 describes the main steps of the log-linear solution. Section 4 presents the simulation of the model under a number of alternative specifications for entry costs and monetary rules. Section 5 concludes. The appendix contains the steady state of the model and the log-linearized equations.

2. The world economy

2.1. Preferences

In each period t, a typical agent i in country $J = H, F$ derives utility from consuming a basket C containing all the goods produced in the world economy while suffering disutility from labor effort, L. Agents maximize the expected discounted value of flow utility U over their life horizon. Flow utility is additive-separable:

$$U_{it}^{J} = \frac{\left(C_{it}^{J}\right)^{1-\rho}}{1-\rho} - \frac{\varphi\chi}{1+\varphi}\left(L_{it}^{J}\right)^{\frac{1+\varphi}{\varphi}} \tag{1}$$

where $\rho > 0$ is the inter-temporal elasticity and $\varphi > 0$ is the Frisch elasticity of labor supply.

The consumption basket C comprises home, C_H, and foreign goods, C_F:

$$C^{J} = \frac{\left(C_{H}^{J}\right)^{\gamma}\left(C_{F}^{J}\right)^{1-\gamma}}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}} \tag{2}$$

where C_H and C_F are given by:

$$\begin{aligned} C_{H}^{J} &= \left[\int_{0}^{N^{H}} C^{J}(h)^{\frac{\theta-1}{\theta}} dh\right]^{\frac{\theta}{(\theta-1)}} \\ C_{F}^{J} &= \left[\int_{0}^{N^{F}} C^{J}(f)^{\frac{\theta-1}{\theta}} df\right]^{\frac{\theta}{(\theta-1)}} \end{aligned} \tag{3}$$

and $\theta > 1$ denotes the elasticity of substitution across varieties. The welfare-based consumer price indexes are given by[4]:

$$P^{J} = \left(P_{H}^{J}\right)^{\gamma}\left(P_{F}^{J}\right)^{1-\gamma} \tag{4}$$

where the producer price indexes P_H^J and P_F^J are:

$$\begin{aligned} P_{H}^{J} &= \left[\int_{0}^{N^{H}} P^{J}(h)^{1-\theta} dh\right]^{\frac{1}{(1-\theta)}} \\ P_{F}^{J} &= \left[\int_{0}^{N^{F}} P^{J}(f)^{1-\theta} df\right]^{\frac{1}{(1-\theta)}} \end{aligned} \tag{5}$$

[1] A non-exhaustive list of contributions in this area includes Ghironi and Mélitz (2005), Corsetti et al. (2007, 2013) and Bilbiie et al. (2007, 2012).

[2] Using US data, Bergin and Corsetti (2008) document that a monetary easing, i.e. a drop in the nominal interest rate, has a positive impact on business formation. See also Lewis (2009) and Uusküla (2008) among others.

[3] An exception is Corsetti et al. (2012). They document that a positive government spending shock crowds out private demand especially in countries with flexible exchange rates. The reason is the rise in investment costs brought about by a depreciating real exchange rate.

[4] The superscript denotes the currency of denomination of the price index. So, P_H^F for instance is the home producer price index in foreign currency.

and $P^J(j)$ denotes the price of a variety $j = h, f$ in the currency of country $J = H, F$.

I assume the law of one price holds for all the goods consumed in the economy, i.e. $P^H(h) = \varepsilon P^F(h)$ and $P^H(f) = \varepsilon P^F(f)$, where the nominal exchange rate ε is the price of currency F in terms of currency H. Given identical preferences, purchasing power parity also holds. In my setup with entry, the assumption is less restrictive than it might appear at first. Firms can in principle insulate the final price of their products from changes in the exchange rate by letting their markups vary according to local market conditions. Simulations will show that this is indeed the case so long as prices are sticky. Clearly, the presence of trade frictions would play a role in the decision whether to access foreign markets in the first place and eventually whether to serve them with exports or by engaging in investments overseas. The analysis of endogenous changes in trade openness or in the mode of accessing foreign markets is beyond the scope of the present paper.[5]

Finally, I define the terms of trade of country F, T, as the price of goods produced in this country relative to the price of goods produced in the partner country:

$$T = \frac{P_F^H}{P_H^H} = \frac{P_F^F}{P_H^F}. \tag{6}$$

2.2. Firms

Producers in the world economy face an identical linear technology with labor as the sole factor. Output supplied by a firm $j = h, f$ in country $J = H, F$ is given by:

$$y_t^J(j) = Z_t^J L_t^J(j) \tag{7}$$

where Z^J is a country-specific shock to labor productivity.

Prior to entry, firms face an exogenous sunk entry cost as in Grossman and Helpman (1991) and Romer (1990).[6] In order to start the production in period $t + 1$, at time t a firm needs to purchase f_e^J units of a combination of home and foreign varieties $f_e^J = (C_H^J)^{\sigma}(C_F^J)^{1-\sigma}$ at the price $P_{f,t}^J = (P_{H,t}^J)^{\sigma}(P_{F,t}^J)^{1-\sigma}$, with $\sigma \in (0,1)$. The cost of entry in units of the consumption basket is therefore $f_e^J \frac{P_{f,t}^J}{P_t^J}$. In this specification, entry requires acquiring a bundle of goods whose composition may differ from that of the consumption basket. Others, as Bilbiie et al. (2007) and Cavallari (2007), specify entry in effective labor units. Entry costs in this case coincide with labor marginal costs.

How to model entry costs is an open question. It has implications for aggregate accounting: labor costs imply a wedge between output of the consumption sector and GDP that is absent with entry costs in terms of product prices. More importantly, it may affect the mechanism of monetary transmission. A monetary easing may in principle have a positive or a negative effect on the cost of entry, depending on how this costs is specified. In a closed economy with labor entry costs, for instance, Uusküla (2008) shows that sticky price models predict a positive relation between firm entry and interest rate innovations in contrast to what found in the data.[7] The reason is that a monetary tightening restrains labor demand, thereby reducing real wages and entry costs. A similar mechanism extends to open economies so long as entry costs comprise domestic goods only. It is, however, conceivable that the costs to setup a new firm have a non-negligible component of imported goods. This is certainly so for investment goods in general and one does not see why first-time investments should be different. As will be clear soon, a monetary expansion leads to business formation in the presence of imported investment goods.

As in 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 $t + 1$, introducing a one-period time-to-build lag into the model. She will eventually exit with an exogenous probability δ. In each period, in addition to incumbent firms there is a finite mass of entrants, N_e^J. Entrants are forward looking and decide to start a new firm whenever its real value, ν^J, given by the present discounted value of the expected stream of profits $\{d_s^J\}_{s=t+1}^{\infty}$, covers entry costs:

$$\nu_t^J = E_t\left[\sum_{s=t+1}^{\infty} \beta(1-\delta)\left(\frac{C_{s+1}^J}{C_s^J}\right)^{-\rho} d_s^J\right] = f_e^J \frac{P_{f,t}^J}{P_t^J}. \tag{8}$$

The free entry condition above holds as long as the mass of entrants is positive. Macroeconomic shocks are assumed to be small enough for this condition to hold in every period. Note that upon entry, firms' profits vary and can even turn negative for a while (although the firm value remains positive). This is a key difference relative to models of frictionless entry where the absence of sunk costs leads profits to zero in every period.

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

$$N_t^J = (1-\delta)\left(N_{t-1}^J + N_{e,t-1}^J\right). \tag{9}$$

2.3. Consumers' choices

I assume complete financial markets within and between countries. Agents can invest their wealth in a set of nominal state-contingent bonds, B, denominated in the currency of country H that span all the states of nature.[8] In addition to state-contingent bonds, they hold a share s of a well-diversified portfolio of domestic firms. The budget constraint of a typical home agent is given by:

$$\sum_{\Omega} q_t^H(\Omega_{t+1})\frac{B_{it}^H}{P_t^H} + s_t^H\left(N_t^H + N_{e,t}^H\right)v_t^H \le \frac{B_{it-1}^H}{P_t^H} + s_{t-1}^H\left(v_t^H + d_t^H\right) + \frac{W_t^H L_{it}^H}{P_t^H} - C_{it}^H \tag{10}$$

where W is the nominal wage. A similar constraint holds for the foreign economy.

Agents choose consumption, labor effort, share and bond holdings in period t so as to maximize utility (1) over their whole life horizon subject to a budget constraint as (10) or its foreign analogue. Consumers' optimization requires the following first order conditions:

$$\frac{q_t^J(s_{t+1})}{P_t^J}\left(C_t^J\right)^{-\rho} = \beta E_t\left[\frac{\left(C_{t+1}^J\right)^{-\rho}}{P_{t+1}^J}\right] \tag{11}$$

$$\left(C_t^J\right)^{-\rho} = \beta(1-\delta)E_t\left[\frac{d_{t+1}^J + v_{t+1}^J}{v_t^J}\left(C_{t+1}^J\right)^{-\rho}\right] \tag{12}$$

[5] In a setup with exporters and multinational firms, Cavallari (2010) shows that the currency of denomination of international trade affects both dimensions of the decision to serve foreign markets.

[6] For a model with endogenous entry costs see, among others, Bergin and Corsetti (2008) and Arespa (2012).

[7] Uusküla (2008) shows that a 1% increase in the Federal Funds rate leads to a 0.6% fall in the entry rate.

[8] Each bond pays one unit of the Home currency if state $\Omega_{t+1} \in \Psi$ occurs at time $t + 1$, where Ψ is a finite set of finitely states that can occur in each period. The price of such a bond at date t is $q^J(\Omega_{t+1})$.

$$C_t^J(h) = \left(\frac{P_t^J(h)}{P_{Ht}^J}\right)^{-\theta} C_{Ht}^J$$
$$C_t^J(f) = \left(\frac{P_t^J(f)}{P_{Ft}^J}\right)^{-\theta} C_{Ft}^J \quad (13)$$

$$\frac{W_t^J}{P_t^J} = \chi\left(L_t^J\right)^{\frac{1}{\varphi}}\left(C_t^J\right)^{\rho}. \quad (14)$$

The Euler equation for bonds (11) together with a no-arbitrage condition in international asset markets, $q_t^H(s_{t+1}) = \varepsilon_t q_t^F(s_{t+1})$, yield the uncovered interest rate parity, UIP:

$$E_t\left(\frac{P_t^H C_t^{H\rho}}{P_{t+1}^H C_{t+1}^{H\rho}}\right) = E_t\left(\frac{P_t^F C_t^{F\rho}}{P_{t+1}^F C_{t+1}^{F\rho}}\right)\frac{1+i_{t+1}^F}{1+i_{t+1}^H}. \quad (15)$$

The assumption of complete markets together with the law of one price and the fact that consumption bundles are identical across countries imply that consumption is equalized worldwide, i.e. $C^H = C^F$.

2.4. Pricing

Goods markets are monopolistically competitive. Each producer sets the price for its own variety facing a downward-sloping market demand:

$$y_t(h) = \left(\frac{P_t^J(h)}{P_{Ht}^J}\right)^{-\theta}\left\{T_t^{1-\gamma}C_t + T_t^{1-\sigma}\left(f_e^H N_{e,t}^H + f_e^F N_{e,t}^F\right)\right\}$$
$$y_t(f) = \left(\frac{P_t^J(f)}{P_{Ft}^J}\right)^{-\theta}\left\{T_t^{-\gamma}C_t + T_t^{-\sigma}\left(f_e^H N_{e,t}^H + f_e^F N_{e,t}^F\right)\right\} \quad (16)$$

where $C \equiv \int_0^1 C_i di$ indicates world consumption.

I introduce nominal rigidities through a Calvo-type contract. In each period a firm can set a new price with a fixed probability $1 - \alpha$ which is the same for all firms, both incumbent firms and new entrants, and is independent of the time elapsed since the last price change. In every period there will therefore be a share α of firms, comprising incumbents and entrants, 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.[9]

The simplifying 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 in my setup with Calvo pricing.

It might have major consequences when 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)). As the number of price-setters that face no cost of adjusting to a past pricing decision moves over the cycle, the aggregate degree of price stickiness becomes endogenous. The analysis of endogenous changes in price stickiness is beyond the scope of this paper.

Each firm $j = h, f$ sets the price for its own variety so as to maximize the present discounted value of future profits, taking into account market demand (16) and the probability that she might not be able to change the price in the future, yielding:

$$P_t^J(j) = \frac{\theta}{\theta-1}\frac{E_t\sum_{k=0}^{\infty}(\alpha\beta(1-\delta))^k \frac{W_{t+k}^J}{Z_{t+k}^J}\frac{y_{t+k}^J(j)}{P_{t+k}^J C_{t+k}^{-\rho}}}{E_t\sum_{k=0}^{\infty}(\alpha\beta(1-\delta))^k \frac{y_{t+k}^J(j)}{P_{t+k}^J C_{t+k}^{-\rho}}} \quad (17)$$

with $J = H, F$. Clearly, when $\alpha = 0$ optimal pricing implies a constant markup $\frac{\theta}{\theta-1}$ on marginal costs at all dates. With $\alpha > 0$, prices respond more or less than proportionally to a marginal cost shock, implying time-varying markups. Markup fluctuations generate a real rigidity at the firm level.

The definition of producer prices together with the fact that the pre-set price level coincides with the average market price in the previous period yield the Calvo state equations corrected for firm entry:

$$\left(P_{Jt}^J\right)^{1-\theta} = \alpha\frac{N_t^J}{N_{t-1}^J}\left(P_{Jt-1}^J\right)^{1-\theta} + (1-\alpha)N_t^J\left(P_t^J(j)\right)^{1-\theta}. \quad (18)$$

Producer prices depend on the stocks of firms active in the current and the previous period so that an increase in the number of producers over time reduces the aggregate price level. This is a consequence of love for variety. A higher number of, say, home varieties raises the value of consumption per unit of expenditure in home goods. Home producer prices must therefore fall.

2.5. Aggregate accounting

Define real GDP in country $J = H, F$ as $Y^J \equiv \int_0^{N^J}\frac{P^J(j)}{P^J}y(j)dj$ where $y(j)$ is given by (16). Goods market clearing requires:

$$Y_t^H = T_t^{2(1-\gamma)}C_t + T_t^{2-\sigma-\gamma}\left(N_{et}^H f_e^H + N_{et}^F f_e^F\right)$$
$$Y_t^F = T_t^{-2\gamma}C_t + T_t^{-\sigma-\gamma}\left(N_{et}^H f_e^H + N_{et}^F f_e^F\right). \quad (19)$$

Labor market clearing implies:

$$L_t^H \equiv \int_0^{\gamma} L_{it}^H di \geq \int_0^{N_t^H}\frac{y_t(h)}{Z_t^H}dh \qquad L_t^F \equiv \int_{\gamma}^{1} L_{it}^F di \geq \int_0^{N_t^F}\frac{y_t(f)}{Z_t^F}df. \quad (20)$$

Aggregating across agents the budget constraint (10) and its foreign equivalent, using the equilibrium conditions $s_{t+1}^J = s_t^J = 1$ and assuming initial financial wealth is zero, yields the accounting equations:

$$Y_t^H - \gamma C_t - N_{et}^H v_t^H = \frac{B_{Ht}^H}{P_t^H} \qquad Y_t^F - (1-\gamma)C_t - N_{et}^F v_t^F = \frac{B_{Ft}^H}{\varepsilon_t P_t^F}. \quad (21)$$

where $B_H^H \equiv \int_0^{\gamma} B_i^H di$ and $B_F^H \equiv \int_{\gamma}^{1} B_i^H di$.[10] In open economies, a discrepancy between output and domestic absorption reflects into a change in net foreign assets (here represented by bonds

[9] The average pre-determined price for home goods P_H^H will be:

$$\left(P_{Ht}^H\right)^{1-\theta} = \frac{\left(P_{H,t-1}^H\right)^{1-\theta}}{N_{t-1}^H}$$

and similarly for P_F^F. These properties are used in deriving the Calvo state equations below.

[10] I used $Y_t^J = \frac{W_t^J L_t^J}{P_t^J} + N_t^J d_t^J$ in deriving the current account equations.

denominated in home currency). Finally, asset market equilibrium requires $B_H^H = -B_F^H$.

2.6. Interest rules

The model is closed by specifying the monetary policy rules in place in the world economy. The monetary instrument is the one-period risk-free nominal interest rate, i_t^J, and monetary policy belongs to the class of feedback rules $1 + i_t^J = f_t^J(\Theta_t)$ where f is a generic function and Θ is the information set at time t.

3. The log-linear model

The model is log-linearized around a symmetric steady state with zero inflation. In the steady state, stochastic shocks are muted at all dates, $Z^J = 1$. This section discusses the main linearized equations while the Appendix contains the steady state and the full log-linearization.

3.1. Demand block

The aggregate demand block is derived from the log-linear approximation to the first order conditions of consumers in the two economies. Consumers allocate their wealth among consumption, nominal risk-free securities 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 the risk-free 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 for shares.

With complete risk-sharing, the bond Euler equations in the two economies can be combined, yielding:

$$E_t\widehat{C}_{t+1} = \widehat{C}_t + \frac{\gamma}{\rho}\left(\widehat{i}_t^H - E_t\pi_{t+1}^H\right) + \frac{1-\gamma}{\rho}\left(\widehat{i}_t^H - E_t\pi_{t+1}^H\right) \tag{22}$$

where a hat over a variable denotes the log deviation from the steady state, $\pi_{t+1}^J = \ln P_{Jt+1}^J / P_{Jt}^J$ is producer inflation in country $J = H, F$ and E is the expectation operator. The above expression says that an increase in the world real interest rate, wherever it is originated, raises the return on bonds, therefore making it more attractive to postpone consumption in the future.

The definition of the terms of trade (6) yields the following state equation:

$$\widehat{T}_t = \widehat{T}_{t-1} + \Delta\widehat{\varepsilon}_t + \pi_t^F - \pi_t^H \tag{23}$$

Movements in the terms of trade around the steady state are driven by changes in the nominal exchange rate and by cross-country inflation differentials. Monetary policy can directly affect the terms of trade through uncovered interest parity:

$$E_t\Delta\widehat{\varepsilon}_{t+1} = \widehat{i}_t^H - \widehat{i}_t^F \tag{24}$$

3.2. Supply block

The supply block is derived from a log-linear approximation to the pricing and entry decisions of firms together with a log-linearization of agents' labor supply. First, consider the optimal price (17) for, say, a home variety. Using market demand (16) and labor supply (14), re-arranging and linearizing gives:

$$E_t\sum_{k=0}^{\infty}\alpha\beta(1-\delta)^k\left[\widehat{P}_{t,t+k}^H + \left(1+\frac{1}{\varphi}\right)(\gamma-1)\widehat{T}_{t+k} - \left(\rho+\frac{1}{\varphi}\right)\widehat{C}_{t+k} + \left(1+\frac{1}{\varphi}\right)\widehat{Z}_{t+k}^H - \frac{1}{\varphi}\widehat{N}_{t+k}^H + \frac{\theta}{\varphi}\widehat{P}_{t,t}^H\right] = 0$$

where $\widehat{P}_{t,t+k}^H = \ln P_t^H(h)/P_{H,t+k}^H$. Note that by definition $\widehat{P}_{t,t+k}^H = \widehat{P}_{t,t}^H - \sum_{s=1}^{k}\pi_{t+s}^H$, namely changes in the real price of a home variety between t and $t+k$ coincide with the variety effect, the first addend, less producer inflation over the period. Using the Calvo state equation (18), the variety effect is:

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

With $\alpha = 0$, an increase in the number of home producers raises the real price of home varieties and the more so the lower the elasticity of substitution θ. This effect is dampened with $\alpha > 0$. Combining the two equations above and re-arranging gives:

$$\pi_t^H = \zeta\left[\frac{(1-\gamma)(1+\varphi)}{\varphi}\widehat{T}_t + \left(\rho+\frac{1}{\varphi}\right)\widehat{C}_t - \frac{1}{(1-\alpha)(\theta-1)}\widehat{N}_t^H - \frac{(1+\varphi)}{\varphi}Z_t^H + \frac{\alpha}{(1-\alpha)(\theta-1)}\widehat{N}_{t-1}^H\right] + \beta(1-\delta)E_t\pi_{t+1}^H \tag{25}$$

where $\zeta = \frac{(1-\alpha\beta(1-\delta))(1-\alpha)}{\alpha(\varphi+\theta)}$.

Producer inflation in the foreign country is obtained in a similar way:

$$\pi_t^F = \zeta\left[\frac{-\gamma(1+\varphi)}{\varphi}\widehat{T}_t + \left(\rho+\frac{1}{\varphi}\right)\widehat{C}_t - \frac{1}{(1-\alpha)(\theta-1)}\widehat{N}_t^F - \frac{(1+\varphi)}{\varphi}Z_t^F + \frac{\alpha}{(1-\alpha)(\theta-1)}\widehat{N}_{t-1}^F\right] + \beta(1-\delta)E_t\pi_{t+1}^F.$$

The country-specific inflation rates depend on next period expected inflation as well as on deviations of the terms of trade, consumption, the number of producers and productivity from their steady state values. These deviations are correlated with current marginal costs as is usual in a new-Keynesian Phillips curve. To begin with, consider an increase in T, i.e. a deterioration in the home terms of trade. The rise in T switches world demand in favor of home products, pushing up labor demand in the home economy. Consequently, real wages and marginal costs rise, fuelling inflation. A similar mechanism explains why a rise in world consumption leads to higher inflation. A rise in home productivity, on the contrary, directly reduces marginal costs. The number of producers is related to inflation via the variety effect. An increase in the stock of producers over time makes a larger range of home varieties available for consumption. Because of love for variety, the value of consumption per unit of expenditure in home varieties increases and producer prices fall. The opposing effect is true for a rise in $\widehat{N}_{t-1}$.

Second, a log-linear approximation to the number of entrants can be obtained from the current account equations (21) as a function of output minus absorption and net foreign assets:

$$\widehat{N}_{et}^H = \frac{\theta(1-\beta(1-\delta))}{\beta\delta}\widehat{Y}_t^H + \left(1-\frac{\theta(1-\beta(1-\delta))}{\beta\delta}\right)\widehat{C}_t - \widehat{v}_t^H - \frac{(1-\delta)}{\delta}\widehat{nfa}_t$$
$$\widehat{N}_{et}^F = \frac{\theta(1-\beta(1-\delta))}{\beta\delta}\widehat{Y}_t^F + \left(1-\frac{\theta(1-\beta(1-\delta))}{\beta\delta}\right)\widehat{C}_t - \widehat{v}_t^F + \frac{(1-\delta)}{\delta}\widehat{nfa}_t \tag{26}$$

where $\widehat{nfa}_t = \widehat{B}^H_t - \frac{1}{\beta}\widehat{B}^H_{t-1}$ and $B^H_t = \frac{B^H_{Ht}}{Y^H P^H_t}$. Note that the resource constraint implies a trade-off between investments in new varieties and consumption of existing goods (the coefficient on C is negative). The law of motion of firms is:

$$\widehat{N}^J_t = (1-\delta)\widehat{N}^J_{t-1} + \delta\widehat{N}^J_{et-1}. \quad (27)$$

Finally, using the property that the aggregate price markup $\mu^J \equiv \int_0^{N^J} \frac{P^J(j)}{W^J/Z^J} dj$ coincides with the inverse of the labor share, $\frac{Y^J P^J}{W^J L^J}$, one can substitute away the real wage in labor supply (14) and together with the GDP definition obtain an expression for aggregate labor. In log-linear terms, this gives:

$$\begin{aligned} \widehat{L}^H_t &= -\rho\varphi\widehat{C}_t + \varphi\left(\widehat{Z}^H_t - \widehat{\mu}^H_t + (\gamma-1)\widehat{T}_t + \widehat{P}^H_{t,t}\right) \\ \widehat{L}^F_t &= -\rho\varphi\widehat{C}_t + \varphi\left(\widehat{Z}^H_t - \widehat{\mu}^H_t - \gamma\widehat{T}_t + \widehat{P}^H_{t,t}\right). \end{aligned} \quad (28)$$

Employment is negatively associated with consumption because of inter-temporal substitution between leisure and labor while raising with the real wage (the term in brackets).

3.3. Interest rate rules

I consider one regime with fixed exchange rates and two floating regimes. The fixed regime is a unilateral peg to the foreign currency featuring a fixed exchange rate at all dates. It is implemented by the interest rule $\widehat{i}^H_t = \widehat{i}^F_t - \varsigma\widehat{\varepsilon}_t$ with $\varsigma > 0$. In this rule, the presence of an exchange target (normalized to zero) ensures determinacy.

In the floating regime, monetary policy follows a symmetric Taylor rule $\widehat{i}^J_t = \phi^J_\pi \pi^J_t$. The Taylor principle, requiring that policy-makers react more than proportionally to inflation, i.e. $\phi^J_\pi > 1$, ensures determinacy. Taylor rules have been extensively analyzed since the seminal paper by Taylor (1993). They are empirically plausible, especially in the last few decades when the objective of price stability has gained a major role in monetary policy-making. In order to account for the need to reduce swings in interest rates in an environment characterized by long and variable lags in monetary transmission, I also consider a variant with interest rate smoothing, i.e. $\widehat{i}^J_t = \phi\widehat{i}^J_{t-1} + \phi^J_\pi \pi^J_t$.

For ease of comparison with flexible price models, I finally consider a Wicksellian regime in which the nominal interest rate is set so as to reproduce a flexible price equilibrium with zero inflation. The Wicksellian interest rates $\widetilde{i}^J$ are given by:

$$\begin{aligned} \widetilde{i}^H_t &= \rho\left(E_t\,\widehat{C}_{t+1} - \widehat{C}_t\right) + (1-\gamma)\left(E_t\,\widehat{T}_{t+1} - \widehat{T}_t\right) \\ \widetilde{i}^F_t &= \rho\left(E_t\,\widehat{C}_{t+1} - \widehat{C}_t\right) - \gamma\left(E_t\,\widehat{T}_{t+1} - \widehat{T}_t\right). \end{aligned} \quad (29)$$

With flexible prices, nominal interest rates mimic changes in the world natural (real) interest rate. As is well-known, the Wicksellian policy can be implemented by means of a credible threat to deviate from a zero inflation target, i.e. $i^J_t = \widetilde{i}^J_t + \vartheta\pi^J_t$ with $\vartheta > 1$.

4. Simulations

The model is simulated using first-order perturbation methods. To begin with, I consider productivity shocks as the main source of business cycle volatility, abstracting from interest rate innovations. This facilitates comparisons with real business cycle models. Next, I focus on a one-time innovation in the nominal interest rate for the purpose of illustrating the mechanism of monetary transmission.

4.1. Calibration

I calibrate a US-EMU model in which country H represents the United States and country F the EMU 12. The relative dimension of the two economies is captured by $\gamma = 0.6$. In the model, the parameter γ also measures the share of domestic goods in US consumption while the analogous share in European consumption is $1 - \gamma = 0.4$. These values are consistent with a higher home bias in the US relative to Europe. The share of domestic goods in US investment is set at $\sigma = 0.4$, lower than that of consumption. For robustness, I let σ vary between 0.2 and 0.8.

In the simulations, periods are interpreted as quarters and $\beta = 0.99$ as is usual in quarterly models of the business cycle. The size of the exogenous exit shock δ is 0.025 as in Bilbiie et al. (2007). The rate of firm disappearance is consistent with a 10% rate of job destruction per year as found in the US. Moreover, such a moderate rate does not overstate the capacity of the model to generate persistence. The elasticity of substitution across varieties θ is equal to 7.88 as in Rotemberg and Woodford (1999a), yielding an average markup of approximately 18%. Studies based on disaggregated data usually find a much lower θ, roughly around 4. Simulations with a lower elasticity deliver qualitatively identical results and will not be reported.[11] Other preference parameters are $\varphi = 2.13$ as in Rotemberg and Woodford (1999a) and $\rho = 1$ as in Bilbiie et al. (2007). I also experiment with a value of the Frisch elasticity as high as 6.

The degree of nominal rigidity is taken from Galì et al. (2001). They find a value of α between 0.407 and 0.66 in the US and between 0.67 and 0.771 in Europe. Following Benigno and Benigno (2008), I take the middle points from these intervals and set $\alpha = 0.49$ in the US and $\alpha = 0.72$ in Europe, implying an average duration of nominal contracts of, respectively 2.3 and 3.65 quarters. I also experiment with a common value of 0.66 as in Rotemberg and Woodford (1999a), obtaining qualitatively identical results. Initial conditions for productivity shocks, the terms of trade and the nominal exchange rate do not affect the dynamics of the model and are set at unity without loss of generality.

Finally, the vector of productivity shocks $Z_t = (Z^H_t, Z^F_t)$ follows a bivariate autoregressive process, $Z_t = AZ_{t-1} + \epsilon_t$ where $\epsilon_t = (\epsilon^H_t, \epsilon^F_t)$ is distributed normally and independently over time with variance V. The correlation between the technology shocks Z^H_t and Z^F_t is determined by the off-diagonal elements of A and V.

4.2. Technology shocks

4.2.1. Moments

This subsection illustrates the performance of the model in replicating stylized facts of the international business cycle. Tables 1A, 1B and 2 report statistics of the time series implied by the model together with statistics in the data. As with the data, all variables are Hodrick–Prescott filtered with a smoothing parameter of 1600. The reported statistics are averages across 100 simulations.

In comparing the model to properties of the data, theoretical variables are divided by relative prices so as to net out the effect of changes in the range of available goods (for any home variable X the corrected measure will be $X^R = XP^H/P^H_H$). As stressed by Ghironi and Mélitz (2005), the correction is necessary because statistical measures of CPI inflation are unable to adjust for availability of new products as in the welfare-based price index. A similar correction applies to the real value of household investments in new firms, $I = \upsilon^H \frac{P^H_H}{P(h)} N^H_e$.

In the benchmark model, entry costs are in terms of goods and monetary policy follows a Taylor rule with interest smoothing $i^J_t = 0.8i^J_{t-1} + 0.3\pi^J_t$. For ease of comparison with other models of firm entry, I also consider a variant with entry costs as wages (see the Appendix for the corresponding linearized equations). Finally, I simulate a flexible price economy with $\alpha = 0$ and the Wicksellian rule $i^J_t = \widetilde{i}^J_t + 1.2\pi^J_t$.

[11] These results are available upon request.

Table 1A
International comovement.

	Benchmark model	Flex price model	Labor entry costs	High σ	Low σ	EU–US data
Correlation of domestic and foreign variables						
Y^R	0.58	−0.78	−0.89	0.50	0.47	0.66
L	0.14	−0.98	−0.98	0.04	0.00	0.33
I	0.28	−0.99	−0.98	0.26	0.21	0.53

First, consider international comovements. In the data, output, consumption, investment and employment are positively correlated across a large number of countries, although cross-correlations are not too strong especially in more recent times (see Ambler et al. (2004)). In addition, the correlation of output is higher than that of any other variable, while the correlation of investments is larger than that of employment. As shown by Backus et al. (1992, 1995), there are important discrepancies between these facts and what standard models predict. Real business cycle models typically generate negative cross-correlations (the comovement puzzle) and fail to match the ranking of cross-correlations in the data (the quantity anomaly). Many candidates have been suggested to alleviate these puzzles, yet no agreement has been reached on what is the best way to solve them.[12] In general, they have been relatively unsuccessful in finding a solution to all the anomalies simultaneously.

Table 1A contains the correlations between home and foreign variables in the benchmark model, in a calibration with $\sigma = 0.8$ or with $\sigma = 0.2$, in the flexible price economy, in the model with labor entry costs and in the data for the United States and Europe from Ambler et al. (2004). Table 1B contains the statistics of home variables in the three models above together with US data from King and Rebelo (1999). To facilitate comparisons, I focus on country-specific productivity shocks with symmetric standard deviation equal to 0.0852, correlation 0.258 and persistence 0.906 as in Backus et al. (1992).

The benchmark model reproduces the positive comovements of output, investments and employment observed in the data.[13] In addition, it matches the ranking in the data with output more correlated than investment and the latter more correlated than employment. On a less positive tone, the cross-correlations of investments and employment are too low. Correlations remain positive although far below those in the data when the share of imports in entry costs is either very low or very high.

In Backus et al. (1992), negative correlations arise as a consequence of an incentive to use inputs where they are most productive. In their model, agents are able to shift substitutable goods between countries and to trade in complete markets for state contingent claims. A positive productivity shock in one country increases the real marginal values of labor and capital compared to the partner country, thereby inducing agents to move production effort to the country with a high technology shock. A similar incentive is at work in a setup with entry whenever prices are flexible or entry requires hiring workers (as will be clear soon, the relative price of investment moves in opposite directions in the two economies). Not surprisingly, the empirical performance of these economies is very close indeed to that of Backus et al. (1992). A near perfect correlation of investments between countries reflects a strong incentive to establish new firms where productivity is high (the home country in the simulation). A negative cross-correlation of employment captures the effect of risk sharing: higher income in the low productivity economy (the foreign country in the simulation) induces agents to reduce labor supply. The combination of these effects leads to a negative correlation of output between countries.

In the benchmark model, movements in the terms of trade affect the relative price of investment in the two economies, amplifying the extent to which a productivity shock spread its effects worldwide. In order to see why consider a positive productivity shock in the home country. In the face of the shock, the price of home-produced goods gradually falls relative to the price of foreign-produced goods, deteriorating the home terms of trade throughout the transition. In the partner country (the low productivity economy) entry costs fall below the present discounted value of expected profits (the value of the firm), thereby stimulating investments in new firms. The rise in the number of producers leads to an expansion in output and employment in both economies (positive comovements). This channel is obscured with entry costs as wages. It works the other way round with flexible prices. As will be clear soon, the home terms of trade appreciate on impact with flexible prices. Therefore, entry costs hike in the foreign country and depress business formation.

It is worth stressing that the ability to match the comovements in the data is not at the cost of the domestic business cycle properties of the model. Table 1B shows that the volatilities of investment and employment in the baseline model are close to the data. The flexible price economy and the model with labor entry costs, on the contrary, display excessive volatility of investments. The intuition is that a high volatility of investments reflects a strong incentive to move production effort in the high productivity country.

Consider now trade variables. Despite ample heterogeneity across countries, a number of stylized facts emerge with clarity. Exports and imports are more volatile than output, positively correlated with each other and pro-cyclical, while net exports are less volatile than output and counter-cyclical (Engel and Wang (2011)). Table 2 reports statistics of home real imports, real exports and the ratio of net exports to GDP in the benchmark model (column a), in a calibration with $\sigma = 0.8$ or with $\sigma = 0.2$, in the flexible price economy (column b), in the model with labor entry costs (column c) and in US data from Engel and Wang (2011). The parametrization of the productivity shock is as before.

The benchmark model matches the properties of trade variables fairly well. It captures the volatility and the pro-cyclical behavior of trade flows together with the counter-cyclical behavior of net exports (in the model as in the data, counter-cyclical net exports derive from a higher correlation of imports with GDP than that of exports). These findings are robust to varying the composition of investments goods across countries. The model performs favorably relative to standard international real business cycle models, as Backus et al. (1992) and Heathcote and Perri (2002), and in line with recent models as Corsetti et al. (2008) and Engel and Wang (2011). Differently from these latter, it replicates the properties of trade flows in a context with complete markets.

In the model, the volatility of trade flows is the result of changes in the range of available goods. In spite of a low elasticity of substitution between home and foreign goods (equal to 1 in the model) and in spite of a low volatility of consumption (the standard deviation of C relative to output is 0.75 in the benchmark model), terms of trade movements induce large swings in the creation of new firms. The

Table 1B
Business cycle properties.

	Benchmark model			Flex price model			Labor entry costs			US data, KR (1999)		
	$\frac{\sigma_X}{\sigma_Y}$	σ_{XY}	ρ_X	$\frac{\sigma_X}{\sigma_Y}$	σ_{XY}	ρ_X	$\frac{\sigma_X}{\sigma_Y}$	σ_{XY}	ρ_X	$\frac{\sigma_X}{\sigma_Y}$	σ_{XY}	ρ_X
Y^R	1	1	0.86	1	1	0.74	1	1	0.61	1	1	0.84
L	1.02	0.95	0.85	0.61	0.91	0.71	1.03	0.99	0.96	0.99	0.88	0.88
I	3.83	0.57	0.81	11.9	0.79	0.56	11.2	0.99	0.63	2.93	0.80	0.87

σ_X is the standard deviation of variable X, σ_{XY} is the correlation of variable X with output, Y, and ρ_X is the auto-correlation of variable X.

[12] Successful strategies comprise, among others, the introduction of non-tradable goods, investment and consumption of durable goods, distribution services, capital market frictions, adjustment costs to investments as well as government spending and taste shocks.

[13] Others have matched the positive comovements in the data, for example Kose and Yi (2006) and Corsetti et al. (2008). However, the cross-correlation of output in these models still falls short of the empirical findings.

Table 2
Trade statistics.

	(a)		(b)		(c)		High σ		Low σ		US data	
	$\frac{\sigma_X}{\sigma_Y}$	σ_{XY}	$\frac{\sigma_X}{\sigma_Y}$	σ_{XY}	$\frac{\sigma_X}{\sigma_Y}$	σ_{XY}	$\frac{\sigma_X}{\sigma_Y}$	σ_{XY}	$\frac{\sigma_X}{\sigma_Y}$	σ_{XY}	$\frac{\sigma_X}{\sigma_Y}$	σ_{XY}
Real imports	3.12	0.78	3.18	0.74	3.59	0.89	2.48	0.69	2.07	0.68	3.34	0.83
Real exports	2.67	0.73	1.79	−0.95	1.72	−0.98	1.50	0.95	1.65	0.96	2.63	0.41
Net exports/GDP	0.22	−0.23	1.72	0.85	2.32	0.98	0.99	−0.64	0.50	−0.56	0.25	−0.47

σ_X is the standard deviation of variable X and σ_{XY} is the correlation of variable X with output, Y. US data are from Engel and Wang (2011). Column a refers to the benchmark model and column b to the flexible price economy and column c to the model with labor entry costs.

adjustment of production capacity at the external margin, in turn, generates a high volatility of external demand in all specifications. A noticeable difference is that exports are counter-cyclical and net exports are pro-cyclical in the models with flexible prices and with labor entry costs. The finding reflects once again a strong incentive to move resources across countries. The drop in business formation in the low productivity economy, in fact, reduces the demand for home exports used as investment goods.

Firm entry provides a mechanism of business cycle amplification akin to the one stressed in models with incomplete markets. Corsetti et al. (2008), for instance, show that consumption risk is magnified by a high volatility of the terms of trade and the real exchange rate as well as by the persistence of productivity shocks. In a similar vein, Engel and Wang (2011) stress the role of durable (traded) goods in generating consumption risk and a high volatility of trade flows. Clearly in my setup with complete markets, the endogenous persistence of productivity shocks implied by firm entry leads to high volatility of trade flows without generating consumption risk.

4.2.2. Impulse responses

Fig. 1 shows the impulse response functions of selected home and foreign variables for 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% deviation) and the horizontal axis shows the number of periods after the shock. For consistency with second moments, the shock has a persistence of 0.906. The impulse responses are displayed under a Wicksellian policy (dotted line), $i_t^J = \tilde{i}_t^J + 1.2\pi_t^J$, and a Taylor smoothing rule (solid line), $i_t^J = 0.8 i_{t-1}^J + 0.3\pi_t^J$.

Focus on the responses under flexible prices (i.e. with the Wicksellian policy). A positive shock to home productivity creates a more favorable business environment, attracting entrants into the home market and

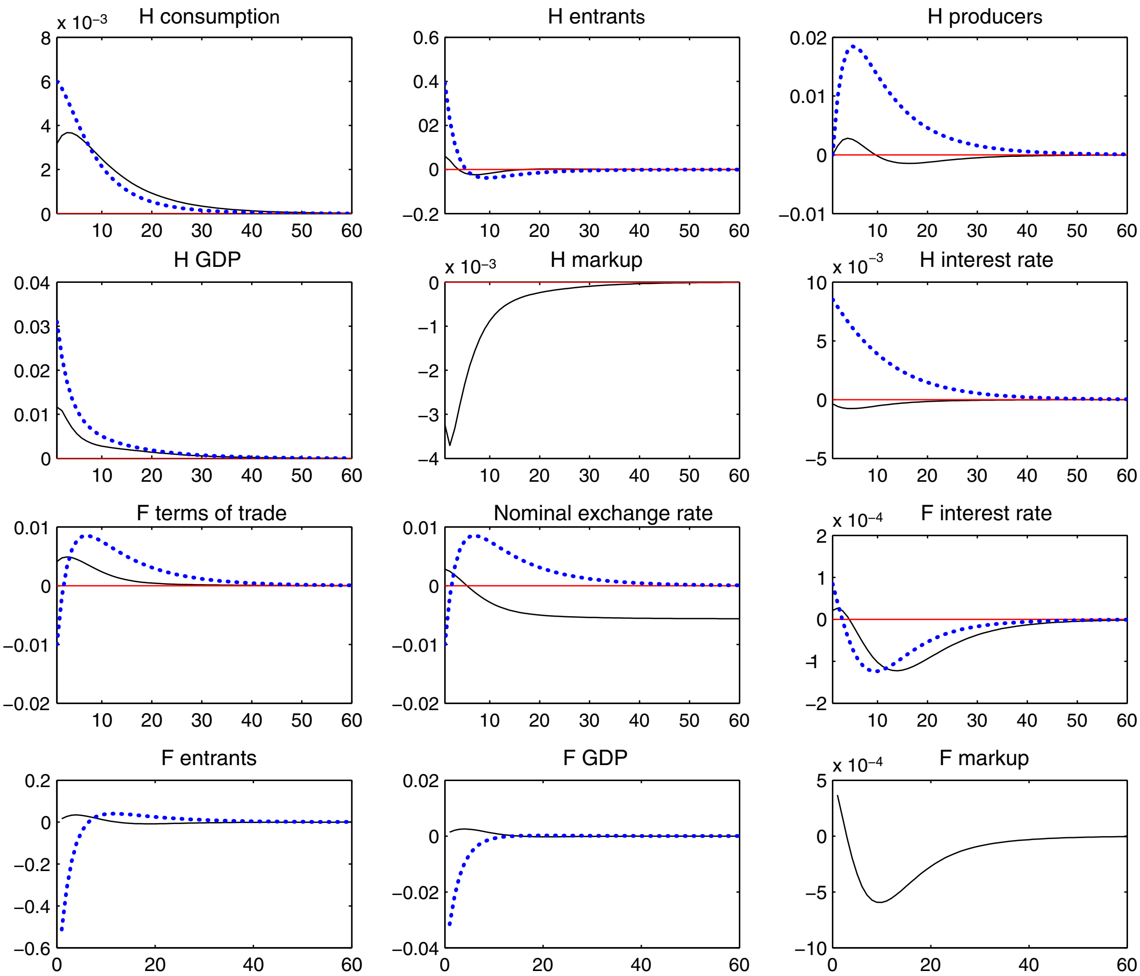

Fig. 1. Impulse response functions for a one-standard-deviation shock to H productivity with sticky prices (solid line) and with flexible prices (dotted line).

leading to a gradual increase in the number of producers over time.[14] A larger number of producers, in turn, raises the relative price of home varieties (the variety effect) together with marginal costs while markups remain unchanged. Because the shock is persistent, there is also a positive wealth effect that pushes up the demand for both home and foreign goods. As a result of all these effects, consumption and GDP hike in the home country.

Trade in goods and assets spreads the effects of the productivity shock worldwide. In response to the productivity rise, the price of home-produced goods falls relative to foreign-produced goods and the home currency appreciates. The home terms of trade sharply appreciate on impact and then gradually deteriorate before converging to the steady state. Consequently, world expenditure switches in favor of home goods for most of the transition. An analogous shift materializes in the portfolio of investors as a consequence of arbitrage in financial markets. In the wake of the productivity shock, the real return on assets (bonds and shares) increases in the world economy. In the high productivity economy (the home country), the rise in the return on shares is brought about by a drop in today's price of equity (the value of the firm) relative to tomorrow's while the opposite is true in the low productivity economy.[15] Therefore business formation increases in the home country while reducing abroad. Note that the response of foreign entrants is the mirror image of that of home entrants. This is a consequence of the fact that a productivity shock favors the production of existing goods relative to the creation of new varieties in the model. Moreover, the drop in the number of entrants and producers reduces foreign GDP for most of the transition. As already noted, a strong incentive to move resources in the most productive economy generates negative comovements between countries.

Comparing the macroeconomic dynamics with sticky and flexible prices reveals a number of interesting features. Consistently with the statistics reported above and in line with new-Keynesian models, sticky prices imply relevant departures from a flexible price equilibrium. First, the response of entrants is subdued, translating into a moderate change in the stock of producers over time. Second, home markups stay below the steady state for the whole transition. In the foreign country, the response of markups is positive on impact then it gradually declines and eventually turns negative before converging to the steady state. Markups are therefore counter-cyclical as observed in the data.[16,17] The behavior of markups is a consequence of a disconnect between prices and marginal costs. On the one side, an increase in the number of producers pushes on labor demand, raising wages and marginal costs. On the other side, only a fraction of producers will be able to adjust the price of their products. These effects, virtually present in any model with entry, may be obscured by offsetting changes in markups or in other sources of marginal costs. The pressure on wages implied by entry is typically accommodated by a drop in firms' markups when firms face costs of price adjustments (see, for instance, Bilbiie et al. (2007), Auray and Eyquem (2011) and Auray et al. (2012)).

Third, output and investment spillovers are positive as in the data. In order to see why, consider entry behavior in the foreign country. Markups above the steady state raise the expected return on investments in new firms. Moreover, improving terms of trade reduce the costs of importing materials for the setup of a new firm (the relative price of investment in terms of the goods produced by domestic firms falls). The combination of these effects reduces today's price of equity relative to tomorrow's, attracting new entrants.

These findings imply a relevant departure from previous models of endogenous entry. In models with labor entry costs, as Bilbiie et al. (2007) and Auray et al. (2012), the introduction of sticky prices has only minor effects. The reason is a direct link between asset prices and inflation that is absent in my setup. Consider, for instance, a temporary interest rate cut that reduces the real return on bonds and shares. The price of equity is related to marginal costs by the free entry condition in these models, therefore marginal costs rise, markups fall and, through the Phillips curve, inflation rises. Sticky prices will have a negligible effect on entry whenever simple monetary rules manage to control inflation, as is the case with Taylor rules. In my setup, instead, the price of equity is related to the cost of acquiring domestic and imported goods. Firm entry depends on the extent to which terms of trade movements in response to productivity shocks affect the price of investment relative to the production of existing goods. Sticky prices indeed matter in this respect.

Furthermore, models with exogenous asset prices (i.e., with entry costs fixed in terms of consumption), as Auray and Eyquem (2011), generate negative comovements at odds with the evidence. In these models, shocks are transmitted through changes in the expected return on assets since the price of investment is tied to the exogenous entry cost. In the country hit by a positive productivity shock, markups rise and more firms enter the market while the opposite occurs in the partner country. In my setup, on the contrary, markups are counter-cyclical. In addition, the price of investment falls (relative to the production of existing goods) in low as well as in high productivity economies, favoring business formation worldwide.

In the benchmark model, declining markups tend to amplify deflationary pressures in high productivity economies while rising markups have the opposite effect in low productivity economies. Monetary authorities have therefore an incentive to move interest rates in a pro-cyclical way in the attempt to stabilize prices (see Fig. 1). Pro-cyclical interest rates, in turn, exacerbate exchange rate volatility via the interest parity. This accords with a large evidence documenting that nominal exchange rates among major currencies revert to their mean value with very long lags.[18] In the model, non-stationarity derives from the state equation of the terms of trade (23), which splits a given change in the terms of trade into changes in the nominal exchange rate and inflation differentials between countries. Although the terms of trade are stationary and revert to the initial value after a shock, there is nothing in the floating regimes considered that forces the exchange rate towards the initial steady state, unless inflation rates are zero at all dates (as with the Wicksellian policy). Mechanically, firm entry contributes to this non-stationarity by generating inflation differentials between countries.

Entry behavior might in principle be affected by the exchange rate regime. Simulations under a unilateral peg in the foreign country, $i_t^F = i_t^H - 0.2\varepsilon_t$, show that this is indeed the case. The responses of investment and output to productivity shocks turn negatively correlated between countries (not shown in Fig. 1). The reason is easy to grasp. Fixed exchange rates (combined with sticky prices) limit the extent to which foreign agents can take advantage of the rise in home

[14] The pro-cyclical response of entry is consistent with ample evidence. In the US, the cyclical properties of entry have been documented by, among others, Dunne et al. (1988), Chatterjee and Cooper (1993), Campbell (1998), Bilbiie et al. (2007) and Lewis (2009).

[15] With flexible prices, profits are a constant share of revenues, $d_t^J = \frac{Y_t^J}{\theta N_t^J}$. Therefore, firm's value (the price of equity) is given by:

$$\nu_t^J = \frac{\beta(1-\delta)}{\theta} E_t\left[\sum_{s=t+1}^{\infty}\left(\frac{C_{s+1}^J}{C_s^J}\right)^{-\rho}\left(\frac{Y_{t+1}^J}{N_{t+1}^J}\right)\right].$$

The real return on shares is $r_{t+1}^J \equiv \frac{\left(\nu_{t+1}^J + d_{t+1}^J\right)}{\nu_{tt}^J}$.

[16] In the US, see Rotemberg and Woodford (1999b) and Bils (1987), among many others. In a panel of 14 OECD countries, Martins et al. (1996) find counter-cyclical markups in 52 out of the 56 cases they consider.

[17] In new-Keynesian models, variable margins of profits are typically powered by exogenous price stickiness. For models that combine variable markups and menu costs see, among others, Gopinath and Itskhoki (2010) and Bhattaraj and Schoenle (2010). Nominal rigidity is by no means essential. In a setup with flexible prices, Atkeson and Burstein (2008) show that firms discriminate prices across markets by letting their markups vary based on local market conditions. Alessandria (2009) points to consumers' search as a reason for variable markups.

[18] In a famous paper, Meese and Rogoff (1983) show that for major nominal exchange rates against the dollar a random walk model outperforms any of the structural models within a one-year forecasting horizon.

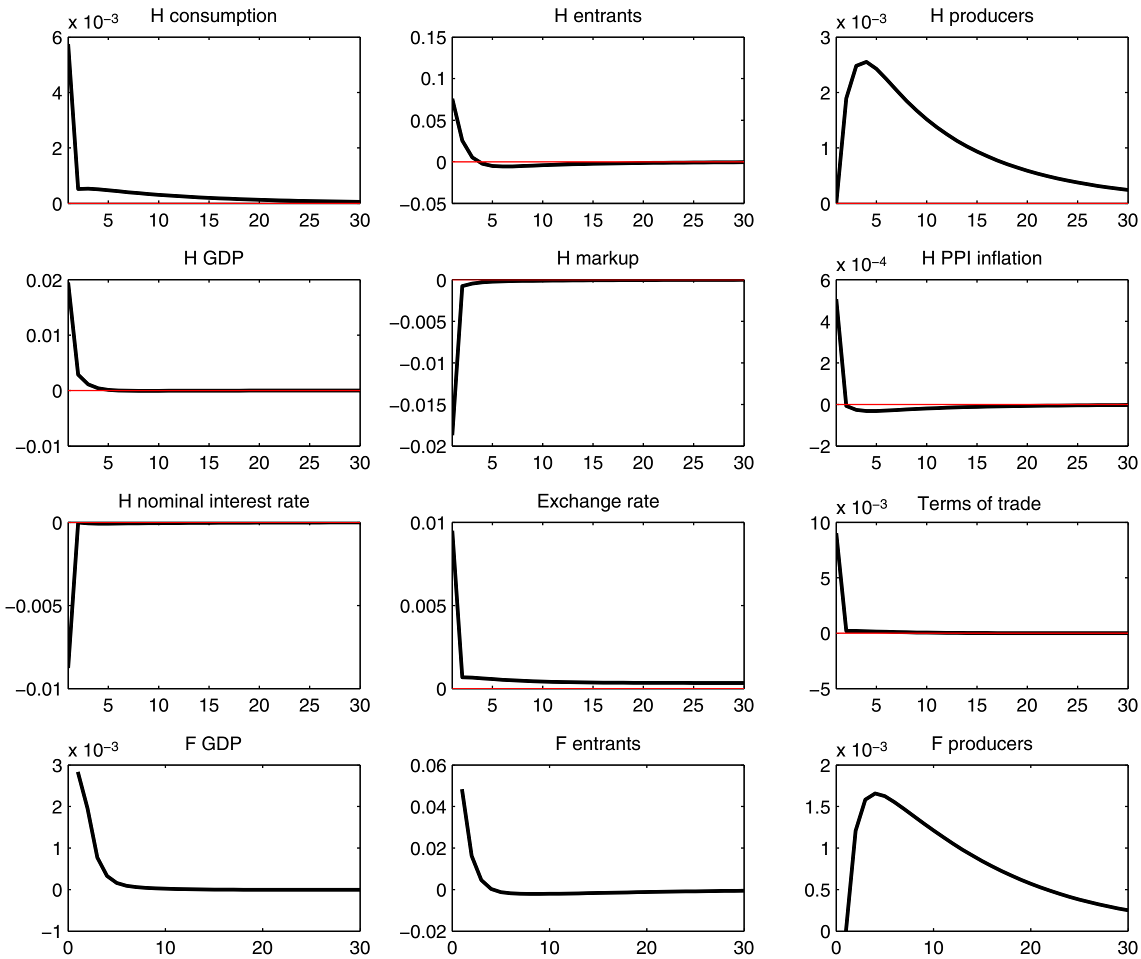

Fig. 2. Impulse responses for a one percent transitory fall in the home interest rate.

productivity, especially in the early part of the transition. By contrast, arbitrage in financial markets requires the real return on assets to increase *immediately* in both economies. In floating regimes, the depreciation of the home currency and the improvement in the foreign terms of trade help bridging the gap between high and low productivity economies. The price of investment in new firms reduces in real terms in the partner country, thereby favoring firm entry. With fixed exchange rates, on the contrary, the relative price of investments in the foreign country raises above the expected discounted value of future profits. Adjustment is brought about by an increase in today's price of equity relative to tomorrow's, thereby deterring investments in new firms.

4.3. Monetary policy shocks

In order to give further insight on monetary transmission in the model, this subsection considers monetary policy shocks. Fig. 2 displays the impulse response functions of home and foreign variables for a one percent transitory cut in the home nominal interest rate. The impulse responses are calculated under a symmetric Taylor rule $i_t^j = 1.5 i_{t-1}^j$ and with the baseline calibration.

The monetary expansion boosts world demand as long as prices are sticky, leading to a spike in world consumption. Over time, as prices slowly return to their natural levels, consumption converges to the steady state. The rise in consumption reflects a drop in the world real interest rate, i.e. a drop in the return on bonds. Arbitrage in financial markets requires the real return on shares to fall as well. The decrease in the real return on shares is brought about by a fall in the return $(v_{t+1} + d_{t+1})$ relative to today's price of equity v_t. The price of equity is tied to the cost of acquiring investments goods by the free entry condition in the model (8). On impact, this cost falls, favoring investments in new firms.

Changes in the terms of trade spread the effects of the monetary easing worldwide. The drop in the home nominal interest rate depreciates the home currency, deteriorating the Home terms of trade.[19] Consequently, world demand shifts in favor of home goods. In my setup, foreign investors take advantage of cheaper home goods (and lower entry costs) by expanding the range of available products. Fuelled by investment demand, foreign GDP stays above the steady state during the whole transition.

Firms might decide to accommodate market demand by increasing their size (the internal margin) as opposed to producing a wider range of varieties (the external margin). Simulations show that they have a strong incentive to adjust production at the internal margin whenever markups are relatively stable over the cycle. In the model, the volatility of markups crucially depends on the elasticity of labor supply. A high φ, by reducing the pro-cyclical movements of wages implied by entry, leads to a lower markup volatility. In the baseline calibration, firms' markups sharply drop on impact, thereby reducing the inflationary consequences of the monetary expansion. In simulations with φ as high as 6 (not shown in Fig. 2), markups are fairly stable, entry is less volatile, inflation is higher and firms' size is larger compared to the baseline case.

[19] Given the assumption of costless trade, the terms of trade are independent of changes in the relative price of non-tradable goods. The role of trade frictions in affecting firm entry and their implications for the transmission of monetary policy shocks is ground for future research.

5. Conclusions

This paper proposes a two-country monetary model with firm entry as a means for alleviating the comovement puzzles in international business cycle models. In a setting with feedback monetary rules and entry costs in terms of product prices, it shows that business formation indeed provides a channel for positive international comovements. Moreover, it helps matching the properties of trade variables in the data. Simulations show that the presence of imported investment goods is essential for replicating these facts.

Appendix A

A1. Steady state

The model is solved in log-deviations from a symmetric steady state equilibrium with zero inflation where $C^H = C^F = C$, $Y^H = Y^F = Y$, $N^H = N^F = N$, $N_e^H = N_e^F = N_e$, $L^H = L^F = L$ and $\varepsilon = T = 1$. Assuming $Z^H = Z^F = f_e^H = f_e^F = 1$, the steady state of the economy is such that:

$$N = \left(\frac{\theta(1-\beta(1-\delta))-\delta\beta}{\beta(1-\delta)}\right)^{\frac{\theta-1}{2-\theta}}.$$

Other variables are given by:

$$i = \frac{1-\beta}{\beta}, \quad v = 1, \quad d = \frac{(1-\beta(1-\delta))}{\beta(1-\delta)}, \quad \mu = \frac{\theta}{(\theta-1)}, \quad \frac{P(h)}{P_H^H} = \frac{P(f)}{P_F^F} = N^{\frac{1}{\theta-1}}$$

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

$$N_e = \frac{\delta}{(1-\delta)} N.$$

A2. Loglinear model

Loglinearized conditions for households are:

$$E_t \widehat{C}_{t+1}^J = \widehat{C}_t^J + \frac{1}{\rho}\left(\widehat{i}_t^J - E_t \pi_{t+1}^J\right)$$

$$E_t \widehat{C}_{t+1}^J = \widehat{C}_t^J + \widehat{v}_{t+1}^J + \frac{1}{\rho} E_t\left(\frac{i+\delta}{1+i} d_{t+1}^J + \frac{1-\delta}{1+i}\widehat{v}_{t+1}^J\right)$$

$$\widehat{L}_t^H = -\rho\varphi\widehat{C}_t^J + \varphi\left(\widehat{Z}_t^H - \widehat{\mu}_t^H + (\gamma-1)\widehat{T}_t + \widehat{P}_{t,t}^H\right)$$

$$\widehat{L}_t^F = -\rho\varphi\widehat{C}_t^J + \varphi\left(\widehat{Z}_t^F - \widehat{\mu}_t^F - \gamma\widehat{T}_t + \widehat{P}_{t,t}^F\right).$$

Loglinearized conditions for firms are:

$$\widehat{N}_t^J = (1-\delta)\widehat{N}_{t-1}^J + \delta\widehat{N}_{et-1}^J$$

$$\widehat{\mu}_t^J = \alpha\beta(1-\delta)\left(\widehat{P}_{t,t+1}^J - \widehat{P}_{t,t}^J + E_t\pi_{t+1}^J\right)$$

$$\pi_t^J = \zeta mc_t^J + \beta(1-\delta)E_t\pi_{t+1}^J$$

where *mc* denotes an index of current marginal costs defined by the term in squared brackets in equation (25) in the main text.

Other log-linear equilibrium conditions are:

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

$$\widehat{Y}_t^J = \widehat{Z}_t^J + \widehat{L}_t^J$$

$$\widehat{Y}_t^H = \frac{(4-3\gamma-\sigma)\beta(1-\delta)}{\theta(1-\beta(1-\delta))}\widehat{T}_t + \left(1-\frac{\delta\beta}{\theta(1-\beta(1-\delta))}\right)\widehat{C}_t + \frac{\delta\beta}{\theta(1-\beta(1-\delta))}\left(\widehat{N}_{et}^H + \widehat{N}_{et}^F\right)$$

$$\widehat{Y}_t^F = -\frac{(-3\gamma-\sigma)\beta(1-\delta)}{\theta(1-\beta(1-\delta))}\widehat{T}_t + \left(1-\frac{\delta\beta}{\theta(1-\beta(1-\delta))}\right)\widehat{C}_t + \frac{\delta\beta}{\theta(1-\beta(1-\delta))}\left(\widehat{N}_{et}^H + \widehat{N}_{et}^F\right)$$

$$\widehat{T}_t = \widehat{T}_{t-1} + \Delta\widehat{\varepsilon}_t + \pi_t^F - \pi_t^H$$

$$\widehat{N}_{et}^H = \frac{\theta(1-\beta(1-\delta))}{\beta\delta}\widehat{Y}_t^H + \left(1-\frac{\theta(1-\beta(1-\delta))}{\beta\delta}\right)\widehat{C}_t - \widehat{v}_t^H - \frac{(1-\delta)}{\delta}\widehat{nfa}_t$$

$$\widehat{N}_{et}^F = \frac{\theta(1-\beta(1-\delta))}{\beta\delta}\widehat{Y}_t^F + \left(1-\frac{\theta(1-\beta(1-\delta))}{\beta\delta}\right)\widehat{C}_t - v_t^F + \frac{(1-\delta)}{\delta}\widehat{nfa}_t$$

$$\widehat{nfa}_t = \widehat{Y}_t^H - \left(1-\frac{\beta\delta(1-\delta)}{\theta(1-\beta(1-\delta))}\right)\widehat{C}_t - \frac{\beta\delta(1-\delta)}{\theta(1-\beta(1-\delta))}\widehat{N}_{et}^H - \gamma\widehat{T}_t$$

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

$$v_t^J = (\gamma-\sigma)\widehat{T}_t.$$

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

In the variant with labor entry costs, the log-linear model is as before except for the following equations:

$$\widehat{v}_t^J = \frac{1}{\varphi}\widehat{L}_t^J + \rho\widehat{C}_t^J - \widehat{Z}_t^J$$

$$\widehat{Y}_t^J = \widehat{Z}_t^J + \widehat{L}_t^J + \widehat{P}_{t,t}^J$$

$$\widehat{Y}_t^H = \frac{2(1-\gamma)(1-\beta(1-\delta))}{\delta\beta N}\widehat{T}_t + \left(1-\frac{\delta\beta}{\theta(1-\beta(1-\delta))}\right)\widehat{C}_t$$

$$\widehat{Y}_t^F = -\frac{2\gamma(1-\beta(1-\delta))}{\delta\beta N}\widehat{T}_t + \left(1-\frac{\delta\beta}{\theta(1-\beta(1-\delta))}\right)\widehat{C}_t.$$

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