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Firms’ entry, monetary policy and the international business cycle

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Abstract

This paper provides a novel theory of the international business cycle grounded on firms’ entry and sticky prices. It shows that under simple monetary rules pro-cyclical entry can generate fluctuations in consumption, output and investment as large as those observed in the data while at the same time providing positive international comovements and highly volatile terms of trade. The capacity to capture these stylized facts of the international business cycle overcomes the well-known difficulties of the standard open economy real business cycle model in this regard. Numerical simulations show that floating regimes exacerbate counter-cyclical markup movements. Fixed regimes, on the other hand, lead to an increase in the volatility of firm entry.

Keywords: product variety, firm entry, international business cycle, monetary policy, interest rate rules, exchange rate regimes.

JEL codes: E31; E32; E52

1 Introduction

This paper provides a novel theory of the international business cycle grounded on firms’ entry and sticky prices. It shows that under simple monetary rules pro-cyclical entry can generate fluctuations in consumption, output and investment as large as those observed in the data while at the same time providing positive international co-movements and highly volatile terms of trade. The capacity to

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capture these stylized facts of the international business cycle overcomes the well-known difficulties of the standard open economy real business cycle model in this regard. In the baseline model of Backus, Kehoe and Kydland (1995), negative co-movements arise as a consequence of the strong incentive to use inputs where they are most productive. In the low productivity economy, input costs rise through factor price equalization and employment and investments fall. This need not be the case as long as a business cycle expansion in one country leads to additional entry in the trading partner’s market. This paper shows that pro-cyclical entry and counter-cyclical markups indeed provide a channel for positive co-movements.

I study business cycle co-movements in 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. The world economy features complete financial markets and full specialization in goods markets.\(^1\) Nominal rigidity is captured by sticky prices 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 two floating regimes, one with symmetric Taylor rules and the other with interest rate smoothing, and a regime where the exchange rate is fixed at all dates. The dynamics of the model under these simple monetary rules is compared with the flexible price equilibrium, the so-called Wicksellian regime. In the model, investments occur at the extensive margin and are driven by the expectation of future profits from introducing a new variety into the market. Investments depend crucially on the monetary rule in place.

In a scenario with flexible prices (where monetary policy is neutral and inflation is zero), potential investors anticipate that they will be able to stabilize their profits by setting prices at a constant markup over marginal costs. A business cycle expansion in one country leads to additional entry in domestic markets with unchanged markups. In the trading partner, risk sharing leads to an increase in income that reduces labor supply (via inter-temporal substitution), raises the costs of inputs and induces firms’ exit. Investments flow in the most productive economy as in the typical real business cycle model, resulting in negative co-movements. Numerical simulations show that the response of new investments to the rise in productivity is extremely large. In the absence of nominal rigidity my model delivers excessive volatility in investments as in the typical RBC model without costs of

\(^1\)Incomplete financial markets are required to explain the near zero cross-country correlation in consumption.

The assumption of risk sharing together with the assumption that all goods are traded imply that agents will in principle be able to move resources (investments and employment) in the most productive economy, thereby generating negative co-movements. They are unable to do so under sticky prices.

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capital adjustment.

Entry behavior turns as volatile as in the data whenever prices are sticky. The prospective of incurring in price distortions in the future discourages potential entrants everything else equal. Remarkably, I find that relevant distortions materialize under all simple monetary rules considered, in fixed as well as in floating regimes, and despite monetary authorities manage to control inflation over the cycle. A more realistic response of investments, in turn, ameliorates the capacity of the model to generate empirically plausible co-movements. Investors anticipate that their profits will fluctuate over the cycle in a pro-cyclical way while their markups will move counter-cyclically as long as prices are sticky. In the low productivity economy, pro-cyclical profits mitigate the negative impact of risk sharing on labor supply, resulting in positive co-movements.

Comparing the dynamics of the model across monetary rules, the paper finds that the exchange rate regime is a key determinant of market entry. In numerical simulations where productivity shocks are the main source of business cycle volatility, floating regimes exacerbate counter-cyclical markup movements. In order to see why, consider a rise in domestic productivity. Home entrepreneurs quickly exploit the profit opportunities associated with falling marginal costs at home and massively enter domestic markets. The price of home varieties reduces and the more so the higher and more persistent the appreciation of the domestic currency. As a consequence, markups will sharply drop in floating regimes. Markup adjustment to (endogenous) changes in exchange rates is compatible with a wide evidence documenting that international goods markets are effectively segmented and the degree of exchange rate pass-through into final prices is far from complete. Fixed regimes, on the other hand, lead to a rise in the volatility of new investments, especially after a monetary policy shock. The finding rests on the capacity of fixed exchange rates to isolate domestic markets from external shocks, thereby providing a safe environment for potential investors. The finding accords with the evidence provided in Bergin and Lin (2008) showing that exchange rate stability positively influences the extensive margin of trade, particularly in monetary regimes that are characterized by a high degree of international policy coordination, as monetary unions and hard pegs.

The paper contributes to a fast-growing literature that investigates the implications of producer entry and product creation for the business cycle propagation and policy.\textsuperscript{2} From a theoretical perspective, these models overcome the unappealing implication of their fixed-variety predecessors that imperfectly competitive markets provide unexploited profit opportunities. The introduction of more realistic assumptions on firms’ dynamics, in turn, appears to ameliorate the capacity of

artificial economies to reproduce empirically plausible patterns for macroeconomic aggregates over the cycle. In a closed economy, Bilbiie, Ghironi and Mélićzt (2005, 2007) show that the moments generated by their models with endogenous entry come very close to the data, outperforming the typical fixed-entry real business cycle model.

Our knowledge, however, is still very limited as regards the role of entry in the international business cycle. In a pioneering paper, Cook (2002) shows that counter-cyclical markups can generate positive co-movements under very strict conditions. It is required a combination of sequential entry, time varying capital utilization and incomplete financial markets. Other early attempts to model entry in open economy have mainly focused on explaining fluctuations in the extensive margins of trade and foreign investment. In all these contributions, monetary policy is either overlooked (as in Ghironi and Mélićzt (2005) and Helpman, Mélićzt and Yeaple (2007), among others) or considered as an exogenous source of business cycle variability (as in Russ (2007) and Cavallari (2007, 2010)). Yet, there are good reasons for studying monetary policy in a model with firm entry. Recent evidence documents that a monetary easing, i.e. a drop in the nominal interest rate, has a positive impact on the number of firms entering the market, suggesting that monetary policy may play a relevant role in a firm’s decision whether to start-up a new production line.3 Open economy models with monetary policy and firm entry include Auray, Eyquem and Poutineau (2010) and Auray and Eyquem (2011). The former finds that a model with entry can replicate the volatility of the extensive margin of trade found in the data. The latter focuses on the cyclical properties of trade flows. Both papers draw on a two-country version of the model in Bilbiie, Ghironi and Mélićzt (2007).

The paper is organized as follows. Section 2 presents the model and the equilibrium conditions. Section 3 provides the main equations of the log-linear model and section 4 presents numerical examples. Section 5 concludes. The appendix provides the steady state and the whole log-linear model.

2 The model

The world economy comprises two countries labelled Home, H, and Foreign, F, each specialized in the production of one type of good as in Corsetti and Pesenti (2002). Each country is populated by a continuum of agents of unit mass. A typical agent in the economy is both a consumer and a worker: he supplies labor services in a competitive labor market and consumes all the goods produced in the world economy. In the Home country, there is a continuum of monopolistically competitive firms,

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each producing a different variety of the Home good \( h \in (0, N^H) \), where \( N^H \) is the number of Home firms. Similarly, in the foreign country there is a continuum of firms \( f \in (0, N^F) \). The stocks of Home and Foreign producers are determined endogenously in the model.

### 2.1 Preferences

A typical agent \( i \) in country \( J = H, F \) derives utility from consuming a composite index of all the goods produced in the world economy, \( C \), and from holding real money balances, \( \frac{M}{P} \), while derives disutility from labor effort, \( L \). 4 Agents maximize the expected discounted value of flow utility \( U \) over their life horizon. Flow utility is assumed additive-separable:

\[
U^J_i(t) = \left( \frac{C^J_i(t)}{1 - \rho} \right)^{1-\rho} + \frac{1}{(1 - v)} \left( \frac{M^J_i(t)}{P^J_i(t)} \right)^{1-v} - \frac{\varphi \chi}{1 + \varphi} \left( L^J_i(t) \right)^{1+\varphi (1)}
\]  

(1)

where \( \rho > 0 \) is the inter-temporal elasticity, \( v > 0 \) the elasticity of real money balances and \( \varphi > 0 \) is the Frisch elasticity of labour supply.

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

\[
C^J = \frac{(C^J_H)^\gamma (C^J_F)^{1-\gamma}}{\gamma^\gamma (1 - \gamma)^{1-\gamma}}
\]  

(2)

where \( C_H \) and \( C_F \) are given by:

\[
C^J_H = \left[ \int_0^{N^H} C^J(h)^{\frac{\theta+1}{\theta}} dh \right]^{\frac{\theta}{(\theta-1)}}
\]

\[
C^J_F = \left[ \int_0^{N^F} C^J(f)^{\frac{\theta+1}{\theta}} df \right]^{\frac{\theta}{(\theta-1)}}
\]  

(3)

The consumer price index is defined as:

\[
P^J = \left( P^J_H \right)^\gamma \left( P^J_F \right)^{1-\gamma}
\]  

(4)

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4Unless otherwise stated, nominal variables are expressed in domestic currency. So \( M^F \), for instance, denotes the amount of money supply in foreign currency.
where

\[ P^j_H = \left[ \int_0^{N_H} P^j(h)^{1-\theta} \, dh \right]^{1/(1-\theta)} \]

\[ P^j_F = \left[ \int_0^{N_F} P^j(f)^{1-\theta} \, df \right]^{1/(1-\theta)} \] (5)

I assume that prices are set in the producers’ currency and that the law of one price holds, i.e. \( P^H(h) = \varepsilon P^F(h) \) and \( P^H(f) = \varepsilon P^F(f) \), where \( \varepsilon \) is the nominal exchange rate defined as the price of currency F in terms of currency H. In this setup with firm entry, the assumption is less restrictive than it might appear at first. Firms can actually insulate the final price of their products from fluctuations in nominal exchange rates by adjusting their markups. Numerical simulations below will show that this is indeed the case. Clearly, trade frictions do 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 the bundle of goods produced in country F relative to the price of the bundle of goods produced in country H:

\[ T = \frac{P^F_H}{P^H_H} = \frac{P^F_F}{P^F_H} \] (6)

### 2.2 Firms

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

\[ y^j_t(j) = Z^j_t L^j_t(j) \] (7)

where \( Z^j \) is country-specific labor productivity. Productivity is exogenous and follows an AR(1) process in percent deviations from the steady state.

Prior to entry, firms face a sunk entry cost \( f^{E,J} \) for starting-up a new production line.6 The cost is defined in units of consumption, i.e. entry requires purchasing a basket of materials of amount \( f^{E,J} \) which has the same composition as the consumption basket, C. Others, as Bilbiie et al. (2007),

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5 Cavallari (2010) provides a model with endogenous entry of export and multinational firms. The currency of denomination of international trade is found to affect both dimensions of the decision to serve foreign markets.

6 One can think of sunk entry costs as administrative fees, licences or any other burocratic accomplishment which is required before entering the market or as the cost for advertising the launch of new products.
Bergin and Corsetti (2009) and Cavallari (2007) among others, define entry costs in effective labor units. Entry in this case requires hiring a certain amount of workers. How to model entry costs is an open question. It has implications for aggregate accounting: with entry costs in units of consumption, for instance, output of the consumption sector coincides with GDP while this is no longer the case when entry costs are in labor units. More importantly, it may affect the mechanism of monetary transmission. A monetary easing can in principle lead to an increase or a drop in the real cost of entry (and therefore to opposing responses on the part of entrants) depending on its effects on marginal costs and total production. Comparing the implications of limited participation versus sticky price models in a closed economy, Uusküla (2008) finds that the predictions based on the production channel, as in the former framework, come closer to the evidence of a negative relationship between interest rate innovations and firms’ entry. In sticky price models, on the contrary, a contractionary monetary shock leads to a drop in market demand and consequently to a drop in the demand for labor. Real wages and marginal costs will therefore fall, thereby favoring entry. As it will be apparent soon, in my setup with entry costs in units of consumption, monetary policy influences entry through the production channel, precisely via its effect on the consumption-investment trade-off.

The entry cost is exogenous. 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.

In each period, there is a finite mass of potential entrants, \( N^{E,J} \). Entrants are forward looking and decide to start a new production line whenever the real value of the new firm, \( \nu \), covers entry costs. Therefore, the free entry condition is given by:

\[
\nu_t^{J} = E_t \left[ \sum_{s=t+1}^{\infty} \beta (1 - \delta) \left( \frac{C_{t+1}^{J}}{C_t^{J}} \right)^{-\rho} d_t^{J} \right] = f^{E,J}
\]

where the expression in square brackets is the present discounted value of future real profits, \( d \).

Finally, the timing of entry implies the following law of motion for the number of producing firms:

\[
N_t^{J} = (1 - \delta) \left( N_{t-1}^{J} + N_{t-1}^{E,J} \right)
\]

2.3 Consumers’ choices

I assume that financial markets are complete within and across countries by allowing agents to trade in a set of nominal state-contingent bonds, \( B \), denominated in the currency of country \( J = H, F \) that
span all the states of nature.\(^7\) In addition to state-contingent bonds, a typical agent holds domestic currency and a share \(s\) of a well-diversified portfolio of domestic firms. His budget constraint is given by:

\[
\sum_{it} q^j_t (\Omega_{t+1}) \frac{B^j_t}{P^j_t} + \frac{M^j_t}{P^j_t} + s_t (N^j_t + N^{E,j}_t) v^j_t \leq \frac{B^j_{t-1}}{P^j_t} + \frac{M^j_{t-1}}{P^j_t} + s_{t-1} (v^j_t + d^j_t)
\]

(9)

where \(W\) is the nominal wage and \(TR\) is a nominal transfer from the government.

Agents choose consumption, labor effort, money, share and bond holdings in period \(t\) so as to maximize utility (1) over their whole life horizon subject to the budget constraint (9). Consumers’ optimization requires the following first order conditions:

\[
\frac{q^j_t (s_{t+1})}{P^j_t} C^{-\rho}_t = \beta E_t \left( \frac{C^j_{t+1}}{P^j_{t+1}} \right)^{-\rho}
\]

(10)

\[
(C^j_t)^{-\rho} = \beta (1-\delta) E_t \left[ \frac{d^j_{t+1} + v^j_{t+1}}{v^j_t} C^{-\rho}_{t+1} \right]
\]

(11)

\[
C^j_t(h) = \left( \frac{P^j_t(h)}{P^H_t} \right)^{-\theta} C^j_{Ht}
\]

(12)

\[
C^j_t(f) = \left( \frac{P^j_t(f)}{P^F_t} \right)^{-\theta} C^j_{Ft}
\]

(12)

\[
\left( \frac{M^j_t}{P^j_t} \right)^{\nu} = \frac{(C^j_t)^{\rho}}{1 - (1 + i^j_{t+1})^{-1}}
\]

(13)

\[
\frac{W^j_t}{P^j_t} = \chi (L^j_t)^{\frac{1}{2}} (C^j_t)^{\rho}
\]

(14)

Note that the Euler equation for bonds (10) together with the no arbitrage condition \(q^H_t (s_{t+1}) = \varepsilon_t q^E_t (s_{t+1})\), yields the risk-adjusted uncovered interest rate parity, UIP:

\[
E_t \left( \frac{P^H_t C^H_{t+1}^{\rho}}{P^H_{t+1} C^H_{t+1}} \right) = E_t \left( \frac{P^F_t C^F_{t+1}^{\rho}}{P^F_{t+1} C^F_{t+1}} \right) \frac{1 + i^E_{t+1}}{1 + i^H_{t+1}}
\]

(15)

\(^7\)There exists a complete set of bonds which pay one unit of the domestic currency if state \(\Omega_{t+1}\) occurs at time \(t+1\). The price of such a bond at date \(t\) is \(q^j_t (\Omega_{t+1})\).
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 risks are fully insured worldwide, i.e. \( C^H = C^F = C \).

Finally, combining the Euler equation for shares (11) with the free entry condition (8) gives:

\[
1 = \beta (1 - \delta) E_t \left[ d_t^{f} \left( \frac{C_{t+1}^J}{C_t^J} \right)^{-\varphi} \right]
\]

In spite of a constant value in present discounted terms, expected profits vary over the cycle. In the model, arbitrage in financial markets requires that expected profits equate the real return on shares, \( E_t \left[ d_t^{f} \right] / f^{J} \), to the real return on bonds in every period. As it will be apparent soon, sticky prices can affect the way these expectations are formed and result in extensive deviations from the entry behavior that would prevail with flexible prices.

### 2.4 Pricing

Goods markets are monopolistically competitive. Each producer sets the price for its own variety facing the following market demand:

\[
y_t(h) = \left( \frac{P_t^J(h)}{P_t^{JH}} \right)^{-\theta} T_t^{1-\gamma} C_t \quad y_t(f) = \left( \frac{P_t^J(f)}{P_t^{JF}} \right)^{-\theta} T_t^{-\gamma} C_t
\]

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 on the time elapsed since the last price change. In every period there will therefore be a share \( \alpha \) of firms, comprising incumbents and entrants, whose prices are pre-determined. In the symmetric equilibrium, pre-determined prices at a given point in time coincide with the average price chosen by firms operating in the market in the previous period. \(^8\)

The assumption that new entrants behave like incumbent firms has the unappealing consequence that a producer may get stuck in a past pricing decision he did not make. It would be plausible to assume that entrants can make their first price-setting decision (at time t+1) in an optimal way. With Calvo pricing, the assumption would imply that the pre-determined price in each period coincides with the average price chosen by firms entered in all previous periods and survived to the

\(^8\)The average pre-determined price for home goods \( P_t^{H} \) will be:

\[
\left( \frac{P_t^{H}}{P_{t-1}^{H}} \right)^{1-\theta} = \left( \frac{P_t^{H}}{P_{t-1}^{H}} \right)^{1-\theta} / N_{t-1}
\]

and similarly for \( P_t^{F} \). These properties will be used in deriving the Calvo state equations below.
death shock, with incumbents and entrants still facing the same price. This clearly has second order effects which become irrelevant in the log-linear model. In a setup à la Rotemberg with quadratic costs of price adjustment, on the contrary, the assumption that entrants are subject to the same nominal rigidity as incumbent firms may have major consequences for the propagation of the business cycle (see Bilbée et al. (2007)). Allowing entrants to make their first price-setting decision at no additional cost would in fact introduce heterogeneity in price levels across cohorts of firms that entered at different points in time. 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 expected discounted value of profits, taking into account market demand and the probability that she might not be able to change the price in the future, yielding:

\[
P_t^J(j) = \frac{\theta}{\theta - 1} \frac{E_t \sum_{k=0}^{\infty} (\alpha \beta (1 - \delta))^k \frac{W_t^J}{Z_t^J} \frac{u_t(j)}{P_{t+k}^J C_{t+k}^J}}{E_t \sum_{k=0}^{\infty} (\alpha \beta (1 - \delta))^k \frac{u_t(j)}{P_{t+k}^J C_{t+k}^J}}
\]

with \( J = H, F \). The expression above can be re-arranged in the familiar form as:

\[
P_t^J(j) = \frac{\theta}{\theta - 1} (1 - \alpha \beta (1 - \delta)) \frac{W_t^J}{Z_t^J} + \alpha \beta (1 - \delta) E_t P_{t+1}^J(j)
\]

where \( P_t^J(j) \) averages a markup on current nominal marginal costs with the expected future price. Clearly, when \( \alpha = 0 \) optimal pricing implies a constant markup \( \frac{\theta}{\theta - 1} \) on marginal costs. With sticky prices, instead, (ex post) markups fluctuate over the cycle. These movements will turn out to play a key role in the international cyclical transmission.

Aggregating the expressions above across firms and using the property that the pre-set price level coincides with the average market price in the previous period, yields the state equations:

\[
(P_{jt})^{1-\theta} = \frac{N_t^J}{N_{t-1}^J} (P_{jt-1}^J)^{1-\theta} + (1 - \alpha) N_t^J (P_t^H(j))^{1-\theta}
\]

9The corresponding average price would be:

\[
(P_{ht})^{1-\theta} = \frac{\sum_{s=2}^{\infty} (1 - \delta)^{s-1} N_t^{E_s} (P_t^H(h))^{1-\theta}}{N_{t-1}}
\]
Observe that the producer price index in each period depends on the current and the past stock of active firms. An increase in the number of producers over time will reduce the aggregate price level everything else given. 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

Governments in the two countries simply rebate all seigniorage revenue in lump-sum transfers to households:

\[
\int_0^1 M_t^H - M_{t-1}^H \, dt + \int_0^1 TR_t^H \, dt = 0 \quad \int_1^2 M_t^F - M_{t-1}^F \, dt + \int_1^2 TR_t^F \, dt = 0
\]  

(20)

Labor market clearing implies:

\[
L_t^H = \int_0^t L_t^H \, dh \geq \int_0^{N_t^H} \frac{y_t(h)}{Z_t^H} \, dh \quad L_t^F = \int_1^t L_t^F \, df \geq \int_0^{N_t^F} \frac{y_t(f)}{Z_t^F} \, df
\]  

(21)

Aggregating the budget constraint (9) across agents, using the government (20) and resource constraint (21) and imposing the equilibrium conditions \( s_{t+1}^i = s_t^i = 1 \) and \( B_{t+1}^i = B_t^i = 0 \) for any \( t \) yields the aggregate accounting equation:

\[
Y_t^J = C_t^J + N_t^E J v_t^J = \frac{W_t^J L_t^J}{P_t^J} + d_t^J N_t^J
\]  

(22)

where \( Y^J \) is real GDP in country \( J = H, F \). Aggregate demand, as given by consumption plus investments in new firms, must be equal to total income (wages plus profits). It is useful at this point to define an aggregate production function with output expressed in units of consumption:

\[
Y^J \equiv \int_0^{N_t^J} P^J(j) y(j) \, dj = Z^J L^J \int_0^{N_t^J} \frac{P^J(j)}{P^J} \, dj
\]

where the second expression follows from labor market clearing. It is easy to show that the expression above satisfies the aggregate constraint (22). Using labor supply (14) together with the property that in equilibrium the inverse of the share of labor, \( \frac{Y^J P^J}{W^J Z^J} \), coincides with the price markup \( \mu^J \equiv \frac{P^J(j)}{W^J Z^J} \), GDP in the two countries amounts to:
\[ Y^H = Z_t^H (1 + \varphi) C_t^{-\varphi \rho} T_t^{(1 + \varphi)^{(\gamma - 1)}} (\mu_t^H)^{-\varphi} \left( \int_0^{N_t^H} \frac{P_t^H(h)}{P_t^H} dh \right)^{(1 + \varphi)} \]

\[ Y^F = Z_t^F (1 + \varphi) C_t^{-\varphi \rho} T_t^{(1 + \varphi)^{\gamma}} (\mu_t^F)^{-\varphi} \left( \int_0^{N_t^F} \frac{P_t^F(h)}{P_t^F} dh \right)^{(1 + \varphi)} \]

(23)

2.6 Interest rate rules

The model is closed by specifying the monetary policy rules in place in the world economy. I assume that the monetary instrument is the one-period risk-free nominal interest rate, \( i_t^J \), and consider the class of feedback rules:

\[ 1 + i_t^J = f_t^J(\Theta_t) \]

(24)

where \( f \) is a generic function and \( \Theta \) is the information set at time \( t \).

3 The log-linear model

The model is solved in logdeviation from a symmetric stationary equilibrium where inflation and exchange rate changes are zero. In this steady state the stochastic shocks are muted at all dates, \( Z^J = f^{E,J} = 1 \). This section discusses the main linearized equations while the Appendix contains the steady state and the full loglinearization.

3.1 Demand block

The aggregate demand block is derived from the log-linear approximation to the first order conditions of consumers in the Home and Foreign countries. 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 must equalize 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 instead relate the inter-temporal profile of consumption to the real return on shares. The real value of the firm, which coincides with the exogenous entry cost in this model, is the forward solution to the Euler equations for shares.

Using the fact that consumption risks are perfectly insured in the world economy, the bond Euler equations in the Home and Foreign countries can be combined, yielding:
where a hat over a variable denotes the logdeviation from the steady state, $\pi^J_{t+1} = \ln P^J_{t+1} / P^J_t$ is producer inflation in country $J = H, F$ and $E$ is the expectation operator. The expression above 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.

From the definition of the terms of trade (6), the following state equation follows:

$$\widehat{T}_t = \widehat{T}_{t-1} + \Delta \widehat{z}_t + \pi^F_t - \pi^H_t$$

(26)

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:

$$E_t \Delta \widehat{z}_{t+1} = \hat{i}^H_t - \hat{i}^F_t$$

(27)

### 3.2 Supply block

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

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

where \( \widehat{P}^H_{t+k} = \ln P^H_t(h)/P^H_{H,t+k} \). Note that by definition \( \widehat{P}^H_{t+k} = \widehat{P}^H_t - \sum_{s=1}^{k} \pi^H_{t+s} \), 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 (19), the variety effect is:

$$\widehat{P}^H_{t,t} = \frac{\alpha}{1 - \alpha} \pi^H_t + \frac{1}{(1 - \alpha)(\theta - 1)} \widehat{N}^H_t - \frac{\alpha}{(1 - \alpha)(\theta - 1)} \widehat{N}^H_{t-1}$$

Combining these two equations and re-arranging gives:
\[ \pi^H_t = \zeta \left[ \frac{(1 - \gamma)(1 + \varphi)}{\varphi} \hat{T}_t + \left( \rho + \frac{1}{\varphi} \right) \hat{C}_t - \frac{1}{(1 - \alpha)(\theta - 1)} \hat{N}^H_t - \frac{(1 + \varphi)}{\varphi} Z^H_t + \frac{\alpha}{(1 - \alpha)(\theta - 1)} \hat{N}^H_{t-1} \right] + \beta (1 - \delta) E_t \pi^H_{t+1} \]

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

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

\[ \pi^F_t = \zeta \left[ \frac{-\gamma(1 + \varphi)}{\varphi} \hat{T}_t + \left( \rho + \frac{1}{\varphi} \right) \hat{C}_t - \frac{1}{(1 - \alpha)(\theta - 1)} \hat{N}^F_t - \frac{(1 + \varphi)}{\varphi} Z^F_t + \frac{\alpha}{(1 - \alpha)(\theta - 1)} \hat{N}^F_{t-1} \right] + \beta (1 - \delta) E_t \pi^F_{t+1} \]

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. Such deviations are correlated with current marginal costs. 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, thereby increasing labor demand in the home economy. With endogenous labor supply, this in turn requires an increase in nominal wages and therefore in marginal costs. A similar mechanism explains why a rise in world consumption is associated with higher marginal costs and higher inflation. A rise in home productivity, on the other hand, directly reduces marginal costs and therefore dampens inflation. Finally, the number of producers is related to marginal costs via the variety effect. An increase in the current stock of producers makes a larger array of varieties available for consumption. Because of love for variety, this in turn increases the value of consumption per unit of expenditure. Consumer prices therefore fall and reduce nominal wages via labor supply. The opposing effect is true for a rise in the number of producers in the previous period. In this case, the variety effect reduces past aggregate prices and wages resulting into higher inflation in the current period.

Second, using the fact that entry behavior is symmetric across firms I derive a log-linear approximation to the number of entrants from the aggregate accounting relation, obtaining:

\[ \hat{N}^{E,J}_{t} = \frac{\theta (1 - \beta (1 - \delta))}{\beta \delta} \hat{Y}^J_t + \left( 1 - \frac{\theta (1 - \beta (1 - \delta))}{\beta \delta} \right) \hat{C}_t \]  

(29)

The law of motion of firms is:
Finally, a log-linear approximation to the GDP equations (23) yields:

\[
\hat{N}_t^J = (1 - \delta) \hat{N}_{t-1}^J + \delta \hat{N}_t^{EJ} \tag{30}
\]

The first four terms in the expressions above capture the effect of changes in employment over the cycle. In this model, only incumbent firms can hire workers (entrants face costs in consumption units and produce with a one-period lag) so that employment changes coincide with the internal margin of output fluctuations. Focusing on Home output, both an improvement in the home terms of trade (a drop in T), an increase in home productivity, a drop in markups and a drop in consumption lead to an increase in labour supply in equilibrium and therefore to higher employment and higher output. For a given number of producers, this in turn implies an increase in firms’ size. The last three terms capture the effects of changes in variety. In a scenario with flexible prices ($\alpha = 0$), output increases only as long as the current stock of producers rises (the external margin of output fluctuations). With sticky prices, these movements become more persistent. Moreover, output changes are positively correlated with inflation.

### 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 $\hat{i}_t^H = \hat{i}_t^F - \zeta \hat{e}_t$ for any $\zeta > 0$. The rule says that the Home nominal interest rate is pegged to the Foreign interest rate and reacts to the deviation of the exchange rate from a desired target (normalized to zero). The exchange target is necessary in order to overcome a potential problem of indeterminacy. In order to see why, consider uncovered interest parity (27): exchange rate expectations are zero whenever the Home and Foreign nominal interest rates are equalized. The simple rule $\hat{i}_t^H = \hat{i}_t^F$, however, would leave the level of the nominal exchange rate undetermined.
The second regime features a symmetric Taylor rule where the nominal interest rate in each
country reacts to producer inflation, i.e. \( \bar{\gamma}_t^J = \phi^J_t \pi_t^J \). The Taylor principle, requiring that policy-
makers react more than proportionally to inflation, i.e. \( \phi^J_t > 1 \), insures nominal determinacy.\(^{10}\) 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.

Finally, I consider a smoothing regime where nominal interest rates depend on their past values.
In particular, I focus on smoothing Taylor rules as \( \bar{\gamma}_t^J = \phi^J_t \bar{\gamma}_{t-1}^J + \phi^J_t \pi_t^J \). The rationale for smoothing
rules draws on the desire to reduce swings in interest rates in an environment characterized by long
and variable lags in monetary transmission.

For ease of comparisons with models that feature flexible prices, I also consider a Wicksellian
regime in which the nominal interest rate is set so as to reproduce the flexible price equilibrium with
zero inflation. The Wicksellian interest rates, \( \tilde{r}^J \), are given by:

\[
\begin{align*}
\tilde{i}^H_t &= \rho (E_t C_{t+1} - C_t) + (1 - \gamma) (E_t T_{t+1} - T_t) \\
\tilde{i}^F_t &= \rho (E_t C_{t+1} - C_t) - \gamma (E_t T_{t+1} - T_t)
\end{align*}
\]

With flexible prices, nominal interest rates mimic changes in the world natural (real) interest rate.
As well-known, the Wicksellian policy can be implemented recurring to a credible threat to deviate
from the zero inflation target. Policy-makers therefore follow the rule \( i_t^J = \tilde{i}_t^J + \vartheta \pi_t^J \) for any \( \vartheta > 0 \).

4 Numerical experiments

In this section I explore the properties of the model by means of numerical examples. In the first
exercise, I focus on productivity shocks as the main source of business cycle volatility, abstracting
from innovations to monetary policy and entry costs, so as to facilitate comparisons with real business
cycle models. In the second exercise, I show the responses in the benchmark economy to a one-time
innovation in the nominal interest rate for the purpose of illustrating the mechanism of monetary
transmission.

\(^{10}\)See Benigno and Benigno (2008) for a proof of the Taylor principle in open economy.
4.1 Calibration

I calibrate a US-EMU model in which country H is the US and country F the EMU 12. As these economies contribute to world production in approximately the same way, I set $\gamma = 0.5$. In the baseline calibration, periods are interpreted as quarters and $\beta = 0.99$ as usual in quarterly models of the business cycle. The size of the exogenous exit shock is $0.025$ as in Bilbiie et al. (2007). The rate of firm disappearance is consistent with a 10 percent 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 goods $\theta$ is equal to 7.88 as in Rotemberg and Woodford (1999a), resulting in a reasonable average markup of approximately 18 percent. Trade studies based on micro data usually find a much lower $\theta$. The qualitative features of the impulse responses below do not change with $\theta = 3.88$.11 The Frisch elasticity $\varphi$ also follows the parametrization in Rotemberg and Woodford (1999a) and is set to 2.13. The inter-temporal elasticity is $\rho = 1$ as in Bilbiie et al. (2007). I experiment a full range of admissible values for $\rho$ and $\varphi$.

The degree of nominal rigidity is taken from Galì, Gertler and Lopez-Salido (2001). The value for $\alpha$ ranges between 0.407 and 0.66 in the US and between 0.67 and 0.771 in Europe. As in 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 in the two countries as in Rotemberg and Woodford (1999a), obtaining qualitatively identical responses. Initial conditions for productivity shocks, the terms of trade and the nominal exchange rate do not affect the dynamics of the model and can be set at unity without loss of generality.

4.2 Technology shocks

4.2.1 Moments

Quantitative properties of the theoretical world economy are reported in Tables 1 and 2 together with properties in the data and in other comparable models. As with the data, statistics refer to Hodrey-Prescott filtered variables with parameter $\lambda = 1600$.

In order to by-pass the difficulty of available measures of inflation to account for variety effects, I express theoretical variables in terms of output whenever necessary, i.e. any variable that in the model is measured in units of consumption will be deflated by producer inflation (multiplied by $P^H / P_H$) and converted into units of output. I measure investments in the model with the real value

11 Responses with $\theta = 3.88$ are available upon request.
of household investments in new firms, \( v^H P^{(h)} N^{EH} \).

Under sticky prices, I assume that monetary policy follows the rule \( i_t^H = 0.8i_{t-1}^H + 0.3\pi_t^H \) in each country \( J = H, F \). This rule is consistent with a large evidence documenting the importance of inflation targets and interest smoothing for monetary policy-making while finding only a marginal significance of GDP responses. With flexible prices, monetary policy follows the Wicksellian rule \( i_t^F = \tilde{i}_t^F + \vartheta\pi_t^F \) defined above.

I start with the co-movements of macroeconomic aggregates worldwide. In the data, co-movements of output, consumption, investments and hours appear to be strikingly positive across a large number of countries, although cross-correlations are not too strong especially in more recent times (see Ambler et al. (2004)). Panel A of Table 1 contains the cross-correlations of output, employment and investment in the benchmark model with sticky prices, in the model with flexible prices, in the model of Backus, Kehoe and Kydland (1995) and in the data for Europe and the US from Ambler et al. (2004). Panel B contains the business cycle properties of the same variables in the three models above and in 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 0.975 as in Backus et al. (1995).

Table 2

A. International Co-movements

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<tr>
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<tbody>
<tr>
<td>Correlations of foreign and domestic variables</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>( Y )</td>
<td>.96</td>
<td>-.61</td>
<td>.66</td>
<td>-.21</td>
</tr>
<tr>
<td>( L )</td>
<td>.20</td>
<td>-.33</td>
<td>.33</td>
<td>-.31</td>
</tr>
<tr>
<td>( N^{EH} )</td>
<td>.39</td>
<td>-.99</td>
<td>.53</td>
<td>-.31</td>
</tr>
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</table>

B. Business Cycle Properties

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<tbody>
<tr>
<td>( C )</td>
<td>1.90 .87 .97 .96</td>
<td>1.67 .22 .42 .97</td>
<td>1.44 .42 -</td>
<td>1.35 .74 .88 .84</td>
<td></td>
</tr>
<tr>
<td>( Y )</td>
<td>2.18 1 1 .97</td>
<td>7.49 1 1 .87</td>
<td>1.50 1 .62</td>
<td>1.81 1 1 .84</td>
<td></td>
</tr>
<tr>
<td>( N^{EH} )</td>
<td>7.91 3.63 .57 .95</td>
<td>49.7 6.63 -.89 .85</td>
<td>20.88 10.99 -</td>
<td>5.30 2.93 .80 .87</td>
<td></td>
</tr>
<tr>
<td>( L )</td>
<td>.72 .33 .97 .96</td>
<td>.14 .02 .03 .84</td>
<td>.95 .50 -</td>
<td>1.79 .99 .88 .88</td>
<td></td>
</tr>
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</table>

\( \sigma_X \) is the standard deviation of variable \( X \), \( \sigma_{XY} \) is the correlation between variable \( X \) and \( Y \) and \( \rho_X \) is the auto-correlation of variable \( X \) between \( t \) and \( t-1 \).

12 Co-movements of consumption are not reported as my model features perfect risk-sharing worldwide.
The model with sticky prices remarkably reproduces positive co-movements of macroeconomic aggregates, overcoming the well-known difficulty of standard open economy real business cycle models in this regard. It provides larger co-movements of output relative to those of employment and investment as in the data, outperforming the model in Backus et al. (1995) also along this dimension. The theoretical cross-correlation of output, however, appears excessively high compared to the data.

In Backus et al. (1995), negative correlations arise as a consequence of the strong incentive to use inputs more intensively in the country where they are most productive. In their model, agents are able to shift perfectly substitutable goods costlessly between countries and to trade in complete markets for state contingent claims. They can therefore move production effort to the country with the current higher technology shock. A similar mechanism applies in the flexible price economy, providing a performance close to that of Backus et al. (1995) in reproducing the international business cycle. In the absence of price distortions within and between countries, investors can establish new firms where productivity is higher (the Home country in the simulation). This reflects in the model as a near perfect negative cross-correlation of investments and a negative correlation of output between countries.

In the benchmark model, investments are much less volatile than with flexible prices (by a factor close to 7) although still more volatile than in the data. My intuition is that a lower volatility of investments under sticky prices reflects the limited ability of agents to move production where it is more productive. In my setup, resources are shifted to the more productive location mainly through investments in new varieties. Potential investors anticipate that failing to set prices in an optimal way will reduce the prospective profits from investing in a new firm for a given level of market demand, thereby discouraging entry relative to the flexible price economy. Moreover, they expect variable profits (and markups) over the cycle. In the low productivity economy, pro-cyclical profits help mitigate the negative impact of risk sharing on labor supply, resulting in positive co-movements.

It is worth stressing that the ability to generate positive co-movements does not come at the cost of implausible business cycle properties. Panel B of Table 1 shows that the model with sticky prices captures pretty well the volatility of output and employment as well as the smoothness of all theoretical variables relative to output. The capacity to generate realistic measures of smoothness is remarkable given the well-known difficulty of standard RBC models in this regard. The volatility of consumption and investment, however, are excessive compared to the data.\footnote{Asymmetric productivity shocks may play a role in this regard. In my setup, a rise in productivity favors consumption of existing goods, implying a higher change in consumption for a given level of market demand (the elasticity of consumption with respect to existing goods is less than the elasticity of substitution across varieties). The volatility of consumption, in turn, is positively related to the volatility of investments via expected profits.} The model displays...
too pro-cyclical patterns for consumption, as typical in RBC models. It outperforms the standard RBC model in capturing the fact that investments are less pro-cyclical than other macroeconomic aggregates, although the correlation with output is too low compared to the data. As regards persistence, theoretical variables are strongly auto-correlated in both the models with sticky and flexible prices while they are typically less persistent than in the data in RBC models.

Consider now the movements in the terms in trade. Despite ample heterogeneity across countries, two stylized facts emerge with clarity. First, the terms of trade are highly volatile, far more volatile than aggregate output although not as much as investments. Second, they are approximately a-cyclical, in the sense that their correlation with output is uniformly very low (Baxter and Crucini (2000)). Table 2 reports the volatility and cross-correlations of the terms of trade, output and investments in the model with sticky and with flexible prices and in the data for the US provided by Baxter and Crucini (2000). The parametrization of the productivity shock is as before.

<table>
<thead>
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<th>Table 2</th>
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<tr>
<td><strong>Model with sticky prices</strong></td>
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<tr>
<td>$\sigma_X$</td>
</tr>
<tr>
<td>$T$</td>
</tr>
<tr>
<td>$\frac{P^h}{P^f}N^E$</td>
</tr>
<tr>
<td>$\frac{p^h}{p^f}Y$</td>
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</table>

$\sigma_X$ is the standard deviation of variable X and $\sigma_X T$ is the correlation between variables X and T.

The model with sticky prices is able to reproduce both empirical regularities. The terms of trade are more volatile than output, more than twice as much in the model and a bit less in the data for the US over the whole period (1955-1990). In line with the findings here, Baxter and Crucini (2000) show that the volatility of the terms of trade has increased significantly after the oil shock in a large number of countries, included the US. The model also captures the fact that the terms of trade are less volatile than investments and positively correlated with the latter. Finally, they are almost a-cyclical as in the data. Under flexible prices, the performance of the model in reproducing plausible business cycle properties deteriorates, showing excessive volatility in all theoretical variables. As noted earlier, high volatility reflects the ability of agents to move resources where they are most productive.

It is worth stressing that my model reproduces key features of the terms of trade without resorting to implausible values for the elasticity of substitution between home and foreign goods. Typically,

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14On average, the standard deviation of the terms of trade has increased from 2.75 before 1973 to as much as 4.27 thereafter. In the US, it jumps to 4.28 in the OPEC period (1973:1 to 1986:4).
RBC models require a very low elasticity in order to generate swings in the terms of trade as large as those observed in the data. In these models, a given change in market demand (net exports) requires a change in prices (the terms of trade) that is higher the lower the elasticity of substitution between home and foreign goods. This has a twofold implication that the volatility of net exports is linked to the volatility of the terms of trade (they are both high in the data) and the former can be increased only at the expense of the latter. In my model, instead, movements in the terms of trade are related to exchange rate changes and inflation differentials between countries.

4.2.2 Impulse responses

Figure 1 shows the impulse responses of Home variables to a 1 percent rise in domestic productivity. The shock has a persistence of 0.975 as in King and Rebelo (1999) for consistency with second moments.

The figure displays the responses under four alternative monetary regimes, all symmetric across countries: 1) the Wicksellian policy (star markers), \( i_t^H = i_t^L + \theta \pi_t^L \), which provides the flexible-price equilibrium; 2) the Taylor rule (discontinuous line), \( i_t^L = 1.5 \pi_t^L \), where nominal interest rates respond to domestic inflation; 3) a rule involving interest rate smoothing (continuous line), which features the same long-run response to inflation, 1.5, as the previous one, \( i_t^L = 0.8 i_{t-1}^L + 0.3 \pi_t^L \); 4) a unilateral peg to the dollar (cross markers), \( i_t^H = 1.5 \pi_t^H \) and \( i_t^E = i_t^H - 0.2 \varepsilon_t \). In the figure the horizontal axis displays the periods after the shock, while responses denote deviations from steady state (a value of, say, 0.01 indicates a 1 percent deviation).

Focus on the responses under flexible prices. The rise in productivity lowers marginal costs and real interest rates with expansionary consequences for consumption and GDP. The favorable business environment, in turn, attracts more firms into the home market and the number of entrants increases. The pro-cyclical response of entry is consistent with ample evidence. \(^{15}\) Note that the response of investments is very large (around 40 percent) as typical in RBC models without costs of capital adjustment. Moreover, entry concentrates in the early stage of the transition with the number of entrants returning to the natural level in around 10 quarters and translating into a gradual increase in the number of producers over time. As more producers compete in home markets, the price of home varieties gradually falls together with marginal costs, leaving markups unchanged.

The Wicksellian policy is counter-cyclical, i.e. the home interest rate stays above the steady state throughout the transition, while it is typically pro-cyclical in closed economies (see Bilbiie et

\(^{15}\) In the US, the cyclical properties of firms’ entry have been documented by, among others, Dunne, Roberts and Samuelson (1988), Chatterjee and Cooper (1993), Campbell (1998), Bilbiie et al. (2007) and Lewis (2009).
Comparing the macroeconomic dynamics with sticky and flexible prices reveals a number of interesting features. Consistently with the business cycle properties already discussed, the responses of entrants are far weaker when monetary policy follows any of the simple (non-optimal) rules considered. The finding is in contrast with previous models of endogenous entry, as Bilbiie et al. (2007) and Auray et al. (2010), where the performance of the sticky price model is virtually indistinguishable from that of the flexible price economy in replicating the business cycle properties of the data. In models with entry costs in units of labor, there is a direct link between share prices and inflation that is absent in my model. Consider, for instance, a drop in inflation that raises the real return on bonds. Arbitrage in financial markets requires a fall in the price of equity which, in turn, induces potential entrants to invest in new varieties. Entry behaviour will be only marginally affected by price stickiness whenever simple monetary rules manage to control inflation, as it appears to be effectively the case in these models. In my setup, instead, share prices are tied to the fixed cost of entry and arbitrage in financial markets requires an increase in expected profits from investing in a new firm. Expected profits, in turn, differ dramatically depending on whether prices are sticky or
flexible. A given change in expected profits requires a much lower change in the number of producers with sticky than with flexible prices (i.e., the elasticity of profits to the number of producer is higher under sticky prices).

Second, the responses of markups are counter-cyclical under simple monetary rules, as in the data.\(^{16}\) In order to see why consider the price distortions that materialize with Calvo pricing. Relative prices within a given period will differ across firms depending on whether they can adjust the price of their own product, introducing a real distortion at the firm level. In the aggregate, home prices will fall on impact, driven by the decline in marginal costs as well as by the pro-competitive effect of entry. Over time, as the number of producers returns to the steady state and prices adjust, deflation gradually disappears. The disconnect between prices and marginal costs determines variable margins of profits throughout the transition.\(^{17}\)

Moreover, markups are more volatile in floating than in fixed regimes. This suggests that a positive relationship might exist between markup adjustment and (endogenous) changes in exchange rates. Despite in my model export prices are fixed in the currency of producers, the dynamics of markups is compatible with less than complete pass-through of exchange rate changes into consumers’ prices. In this sense, the sharp drop in markups that materializes in floating regimes allows to (partly) insulate final prices from exchange rate volatility. The interpretation is confirmed by the fact that the standard deviation of exchange rates in my artificial economy is larger than the standard deviation of consumer prices under all simple monetary rules considered.\(^{18}\) Markup adjustment in export markets is empirically plausible, as a wide evidence documents that international goods markets are indeed segmented and pricing to market practices are widely diffused.\(^{19}\)

Third, changes in nominal exchange rates are highly persistent. This accords with a large evidence

\(^{16}\)Studies based on different methodological approaches converge on the view that markups are counter-cyclical in major economies. In the US, this is indeed the case for studies that use mostly aggregate data as Rotemberg and Woodford (1999b) as well as two digit industry level data as in Bils (1987). In an analysis that covers 14 OECD countries and industry level data, Martins, Scarpetta and Pilat (1996) find counter-cyclical markups in 52 out of the 56 cases they consider.

\(^{17}\)In models with quadratic costs of price adjustment, as Bilbiie et al. (2007), counter-cyclical markups may emerge as a consequence of pro-cyclical movements in these costs. Markups are clearly constant under the optimal rule. With flexible prices, in fact, the rise in productivity reduces marginal costs and the relative price of each product in exactly the same proportion, leaving markups unaltered at the firm level and in the aggregate. This implies that all relative prices adjust completely, i.e. they move one to one with the productivity shock, and so does the real value of investments. Clearly, producer inflation is zero.

\(^{18}\)In models with a fixed number of varieties which do not explicitly allow for deviations from the law of one price, as in Benigno and Benigno (2008), the volatility of consumer prices is bound to equalize the volatility of the nominal exchange rate or, in other terms, the real exchange rate is constant.

\(^{19}\)See Goldberg and Knetter (1997), Engel and Rogers (1996) and Campa and Goldberg (2005), among others. Studying markup adjustment in the automobile export market of Japan, the US and Germany, Gagnon and Knetter (1995) find that markup dynamics is in general compatible with pricing to market. The relation between markups and exchange rates is particularly strong in Japan and to a lesser degree in Germany. It is virtually absent in US export markets.
documenting that nominal exchange rates among major currencies revert to the mean value with very long lags.\textsuperscript{20} In the model, non-stationarity derives from the state equation of the terms of trade (26), 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 (as with the Wicksellian policy). Mechanically, entry contributes to this non-stationarity by generating inflation differentials between countries. With sticky prices, monetary authorities have an incentive to move interest rates pro-cyclically so as attract entry in domestic markets. Pro-cyclical interest rates movements, in turn, exacerbate exchange rate volatility. Under flexible prices, instead, interest rates are counter-cyclical. These findings reflect a different orientation of monetary policy in floating regimes. In a world with flexible prices, policy-makers passively accommodate changes in the natural interest rate (which moves counter-cyclically) and let the exchange rate fluctuate consequently. When prices are sticky, on the contrary, they face a trade-off between the need to stabilize producer inflation on the one hand and to attract investments on the other hand.

In order to evaluate international co-movements, consider the responses of domestic macroeconomic aggregates to a 1 percent rise in foreign productivity in Figure 2. The persistence of the shock is 0.975 as in the Home country.

The boost in productivity has a positive impact on world consumption in all regimes, independently of whether it originates at home or abroad. In floating regimes, the responses of consumption are very close indeed to the responses in Figure 1. The motives are essentially the same: the rise in productivity lowers real interest rates and attracts investments (abroad, in this case), thereby stimulating world consumption.

The rise in foreign productivity propagates its effects worldwide through the movements in the terms of trade and the standard expenditure switching effect. With flexible prices, the deterioration of the foreign terms of trade during most of the transition reduces the demand for home goods over the whole investment horizon and results in a drop of home varieties. The sharp fall in the number of home entrants, in turn, is responsible for the negative co-movements discussed earlier.

With sticky prices, the expenditure switching effect is dampened, especially in floating regimes where the home currency depreciates. As a consequence, home agents moderately expand their investments in new firms. Investment and output co-movements are positive, in accordance with the

\textsuperscript{20}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.
Figure 2: Responses to 1 percent a rise in foreign productivity with Wicksellian policy (star marker), Taylor rule (discontinuous line), smoothing rule (continuous line) and fixed exchange rates (cross marker).

evidence already discussed. This contrasts with the finding in Auray et al. (2010). In their model, as in my scenario with flexible prices, negative output spillovers arise as a consequence of a (too) sharp drop in home investments.

The responses of markups in Figure 2 are compatible with the idea of markup adjustment in export markets as discussed above. In floating regimes, the rise in foreign productivity is associated with higher inflation in the partner country. Home producers, in fact, respond to the depreciation of the home currency by raising the price of their products in domestic currency. Fewer home varieties will therefore be produced and the markups of home producers will stay above the steady state in the first stage of the transition. With fixed exchange rates, on the contrary, home producers need to reduce the price of their products in order to maintain their competitiveness. Consequently, more varieties will be produced and markups will fall throughout the transition.

4.3 Monetary policy shocks

In order to give more insights on the international monetary transmission with endogenous entry, consider the responses of macroeconomic aggregates to monetary policy shocks. Figures 3 and 4 show the responses to a one percent purely transitory fall in, respectively, domestic and foreign interest rates. In this exercise, parameters are as in the standard calibration.\(^{21}\) The impulse responses are

\(^{21}\)I have also experimented with different combinations of the elasticities \(\rho\) and \(\varphi\), obtaining responses qualitatively identical.
Figure 3: Responses to a 1% fall in the home interest rate with producer inflation target (continuous line) and consumer inflation target (dotted line)

calculated under interest rate smoothing with either a producer inflation target (continuous line) or a consumer inflation target (discontinuous line).

The responses of consumption in Figures 3 and 4 are qualitatively similar as one would expect with perfect risk sharing. The monetary expansion, wherever it is originated, boosts world demand as long as prices are sticky, leading to a spike in world consumption in the early stage of the transition. Over time, as prices slowly return to their natural levels, world consumption declines for a while before converging to the steady state. Notice that despite the shock is purely transitory, the dynamics of macroeconomic aggregates displays a significant degree of persistence as one observes in the data.\(^{22}\)

The rise in global consumption must be accommodated by a corresponding increase in global output. Depending on the movements in the terms of trade, a given change in world consumption can be associated with different changes in home and foreign output.\(^{23}\) As long as the home terms of trade improve, as under a monetary expansion abroad, home agents can work less for a given level of consumption, raising their welfare at the expense of foreign consumers (the so-called terms of trade externality). Clearly, the opposite occurs with deteriorating terms of trade. The country of origin of the shock is therefore crucial for understanding monetary transmission in open economies.

To start with, focus on the home shock (Figure 3). The fall in the home interest rate leads to

\(^{22}\)The responses with monetary rules that do not feature interest rate smoothing (available upon request) show some persistence as well, albeit over a shorter time horizon.

\(^{23}\)Given the assumption of costless trade, movements in the terms of trade are independent of changes in the relative price of non-tradables in my model. The role of trade frictions in firm entry and their implications for the transmission of monetary policy shocks worldwide is ground for future research.
a devaluation in the domestic currency via uncovered interest parity. Note that the devaluation is persistent when the monetary target is producer inflation. With consumer inflation targeting, instead, the exchange rate is fixed throughout the transition (except for a slight devaluation on impact). The stabilization of consumer inflation comes at the cost of an increase in producer inflation. Moreover, it affects how a given change in the terms of trade is split between exchange rate changes and inflation differentials. As I will discuss in a while, this has non-negligible consequences for entry. Deteriorating terms of trade, in turn, shift demand in favor of home goods, while reducing real wages (recall labor supply (14)) and increasing employment in the home economy (not shown in Figure 3). In the absence of fixed costs, incumbent producers take advantage of the favorable market conditions and increase investments along the intensive margin (not shown in Figure 3). The response of entrants, on the contrary, is hump-shaped with a sharp drop in the early stage of the transition and a moderate rise thereafter. This is a consequence of two opposing effects at work in the model. On the one side, entrepreneurs are induced to start-up new firms so as to exploit the favorable business environment in the aftermath of the monetary easing. On the other side, however, inflation and deteriorating terms of trade raise the cost of new investments in terms of output, thereby discouraging entry.24

In the data, the response of entry to monetary policy shocks is hump-shaped, suggesting that in addition to entry costs other frictions may prevent potential investors from quickly exploiting new profit opportunities. My findings suggest that sticky prices may indeed be one such frictions.25 Empirical evidence further documents that entry reacts positively to an unexpected drop in the nominal interest rate (see Bergin and Corsetti (2009), Lewis (2009) and Uusküla (2007)). This might seems at odds with the response in Figure 3 (yet in line with the one in Figure 4). The conflict, however, is less severe than it might appear at first. Entry responds with a significant lag in the data, implying that the theoretical responses are empirically plausible over the relevant horizon.26 Moreover, the correlation between the number of entrants and nominal interest rates in the model is negative as in the data.

Consider the responses of domestic variables to a monetary easing abroad (Figure 4). Consumption bursts as before (recall complete risk-sharing) yet with opposing consequences for supply-side variables. Now, the home terms of trade improve, thereby reducing the real cost of investments and

24In Bilbiie et al.(2007), firms’ start-ups reduce throughout the whole transition. In their model, a monetary expansion raises the real cost of investments via its effect on asset prices (a drop in the interest rate reduces the real return on bonds and shares, therefore augmenting share prices and entry costs).
25Auray et al. (2010) similarly find that interest rate changes over the cycle (in response to productivity shocks in their case) may raise entry costs long as prices are sticky. In their model, however, this effect is negligible.
26Using VAR estimates, Lewis (2009) shows that the response of entry to monetary policy shocks is significant only at medium run horizons.
inducing home entrepreneurs to start-up new production lines. I stress that the response of entrants is particularly high whenever exchange rates are fixed as under consumer inflation targeting. The reason lies in the sharp fall in the price of domestic varieties (and hence in the real cost of starting up a new production line) that materializes in this case. The finding accords with a wide evidence showing that exchange rate stability positively influences the extensive margin of trade, particularly whenever there is a high degree of monetary policy coordination worldwide, as in monetary unions and hard pegs.27

Comparing the responses of entry in Figures 3 and 4 reveals that a positive relationship exists between movements in the terms of trade and investments along the extensive margin. Entry in home markets is favored whenever the monetary expansion originates in the foreign country (and is therefore associated with appreciating terms of trade) and the more so in fixed than in floating regimes. The opposite occurs with a monetary easing at home. The finding that the country of origin of monetary uncertainty matters for the investments decisions of firms in open economy is compatible with a recent evidence documenting that an increase in monetary volatility may have contrasting effects on the decision whether to invest abroad. 28

27 Flam and Nordstrom (2006) show that the creation of the euro has led to an increase in trade along the extensive margin. See also Berthou and Fontagné (2008) and Auray et al. (2010). Bergin and Lin (2008) document that trade flows change mostly along the intensive or the extensive margin depending on the monetary regime in place. They show that movements along the extensive margins are mainly associated with hard pegs while movements along the intensive margin prevail under soft pegs.

28 Russ (2009) finds that exchange rate changes due to home monetary volatility deter US multinationals from starting-up new facilities abroad while the opposite is true with an increase in foreign volatility. In a panel of OECD
Figure 5: Responses to a 1% rise in home productivity with entry (continuous line) and without entry (dotted line)

Up to now, I have argued that monetary policy has a relevant influence on firms’ dynamics. One might wonder what implications this bears for monetary policy. In other terms, what happens if monetary policy neglects the entry channel? In order to investigate the issue, I compare macroeconomic dynamics in the model above with the one that would arise in the absence of an endogenous response of entry. In this exercise, I focus on productivity shocks as the source of business cycle volatility. Figure 5 shows the responses of consumption, output, the terms of trade and the nominal interest rate to a 1% rise in home productivity in the model with entry (continuous line) and in the model without entry (discontinuous line). Endogenous variables are normalized so as to express the gap with respect to their natural counterparts. All parameters are as in the standard calibration. The monetary rule involves producer inflation targeting and interest rate smoothing.

Interestingly, nominal interest rates respond less in the model without entry than in that with entry. I have already argued that interest rates move counter-cyclically in the Wicksellian scenario because of the terms of trade externality, (in this case, the rise in the interest rate is aimed at appreciating the domestic currency and improving the home terms of trade so as to reduce the benefits of the productivity boost accruing abroad). Neglecting the impact of interest rate changes on new investments further widens this gap (by a measure as high as 1.5 per cent) and results in a sub-optimal response of the terms of trade. This in turn leads to an extremely slow adjustment of economies. Cavallari and D’Addona (2010) show that FDI outflows are discouraged by an increase in monetary volatility in the source country. Changes in monetary volatility that originate in the destination country, instead, do not appear to have a significant effect neither on the decision whether to invest abroad in the first place nor on the amount of the investment.

For each variable $x_t$, the gap $x_t^{GAP}$ is defined as $x_t^{GAP} = x_t - \bar{x}_t$. 29
output (it takes approximately 40 periods for bridging the output gap in the model without entry compared to 10 periods in the model with entry). The consumption gap, on the contrary, is almost unaffected by entry.

5 Conclusions

This paper developed a model of international business cycle transmission with an endogenous number of producers and feedback monetary rules. The model shows that accounting for firms’ dynamics under simple monetary rules allows to reproduce key facts of the international business cycle, outperforming the typical open economy real business cycle model with a fixed number of variety along several dimensions. Remarkably, I find that pro-cyclical entry and counter-cyclical markups give rise to positive co-movements of macroeconomic aggregates over the cycle and stronger co-movements of output relative to those of employment and investments, overcoming the well-known difficulty of standard models in this regard. Moreover, my model can replicate the cyclical properties of the terms of trade found in the data without resorting to implausible values for the elasticity of substitution between home and foreign goods.

References


6 Appendix

6.1 A Steady state

I solve the model in logdeviation from the symmetric steady state equilibrium without inflation where $C^H = C^F = C$, $Y^H = Y^F = Y$, $N^H = N^F = N$, $N^{EH} = N^{EF} = N^E$, $L^H = L^F = L$ and $\varepsilon = T = 1$. Assuming $Z^H = Z^F = f^{EH} = f^{EF} = 1$, the steady state of the economy is such that:

$$N = \left[ \left( \frac{\theta}{(\theta - 1)} \right)^{\varphi(1-\theta)} \left( \frac{\theta (1 - \beta (1 - \delta)) - \delta \beta}{\beta (1 - \delta)} \right)^{(1+\varphi\rho)(1-\theta)} \right]^{\frac{1}{1+\varphi\rho(\theta-1)+\varphi\rho}}$$

Other variables are given by:

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

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

6.2 B Loglinear model

TBW