Macroeconomic volatility and international integration

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This paper explores the effects that varying degrees of international openness have on macroeconomic volatility. The analysis is conducted for a two-symmetric-country world under three levels of international integration: that of a closed economy, a financial autarky and full financial integration. Different degrees of trade openness are considered in the form of home biases, while the economy is left vulnerable to total factor productivity and innovation shocks. Full financial integration is found to reduce firm-size volatility and volatility in the mass of operative firms following a productivity shock and to increase them after an innovation shock. Moreover, the interaction between international sharing of profits and terms of trade transmissions determines the nonlinear behaviour of consumption-to-output ratio volatility found in empirical studies.

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I. Introduction

How do trade and financial integration affect macroeconomic volatility? To date, neither empirical studies nor the theoretical literature seem able to agree on their impact. Consequently, the aim of this paper is to develop a theoretical model that, simultaneously considers, trade and financial globalisation. Thus, in addition to analysing each type of integration separately, it is able to capture the potential consequences of interactions between these two dimensions on macroeconomic volatility.

Financial integration is supposed to serve as a cushion against adverse domestic shocks by allowing for lending and borrowing from abroad, which should lead to a decline in consumption volatility (Bekaert et al. (2006)). However, financial integration also increases the potential for the magnification of financial shocks and, so, output and investment volatility may increase (Mendoza (1994)). Empirical papers report that financial openness is associated with an increase in the consumption-to-output volatility ratio, as opposed to the theoretical risk-sharing benefits of capital globalisation Indeed, Kose et al. (2003) find a nonlinear relationship between financial integration and consumption-to-output volatility. Until the 1990s, this volatility increased for more financially integrated developing economies but not for industrial economies. Moreover, consumption volatility was found to increase with financial integration up to a certain threshold; however, any further integration led to a reduction. The model proposed here provides theoretical support for this

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nonlinearity. Evans and Hnatkovska (2007) have previously addressed this issue with a two-sector, two-country theoretical model, finding the same nonlinearity highlighted in Kose et al. (2003). However, these two papers abstract from trade integration, which may have left part of the explanation hidden due to the potential interaction between the processes of trade and financial integration processes.

In spite of the financial integration experienced by OECD countries over the past decades, Buch et al (2005) show that there has been no consistent pattern with regards to consumption volatility: changes in volatility over time often depend on the country and the period of time and not exclusively on the higher level of financial integration. The authors explain this inconsistent correlation (between changes in volatility and the degree of integration) in terms of the fact that the link between consumption and output volatility with financial globalisation depends on the source of the shock. To capture this, here I consider two distinct sources of shock and analyse how the volatility they generate is amplified or reduced with globalisation.

The debate concerning the link between trade openness and aggregate volatility is equally open. Caselli et al. (2012) find a negative theoretical link between trade integration and output volatility, in contrast with the traditional view upheld by Newbery and Stiglitz (1984). On the empirical side of the literature, Easterly et al. (2001) , using data for a sample of 74 countries over the period 1960-97 conclude that greater trade openness leads to higher volatility of output and consumption; while Kose et al. (2003) also point to the existence of a positive effect on volatility due to a greater vulnerability to external shocks. Finally, Prasad et al. (2003) document that over recent decades consumption volatility has declined in developed economies and increased in their developing counterparts. This evidence may demonstrate the interaction between financial and trade integration highlighted in the report conducted by the IMF (2002).

I use a two-symmetric-country model with the endogenous entry of firms to address the issue. I undertake a quantitative analysis, based on computational simulations of three scenarios: a closed economy, a financial autarky and a fully integrated economy, which are subject to innovation and Total Factor Productivity (TFP)shocks. I compare how macroeconomic volatilities evolve as countries move between scenarios, and for different degrees of trade openness, and explain some of the ambiguity found in the empirical literature. In particular, I find that the nonlinear behaviour of the volatility of the consumption-to-output ratio for different degrees of globalisation has its origins in the different effects of innovation and TFP shocks during the process of opening up. The quantitative exercise shows that idiosyncratic TFP shocks alone are unable to produce the nonlinearity. Indeed, a country opening up its capital market may suffer from an increase or decrease in its macroeconomic volatility, relative, that is, to a financial autarky, depending on the source of the shock (in line with Buch et al. (2005)) and on the degree of trade openness, which indicates that both mechanisms of integration interact (in line with IMF (2002)). Finally, a closed economy opening up to trade reduces all volatilities except that of the ratio between consumption and output.

The introduction of the extensive margin (endogenous number of firms) in the goods market is necessary to capture a relevant source of volatility in the trade dimension. It is a well-known fact that international trade has increased dramatically over recent decades and that a large share of this increase has been in the number of varieties exchanged, rather than in actual quantities (intensive margin).[2] The contributions of firm entry and product variety to the understanding of the business cycle have been analysed in Ghironi and Melitz (2005), Bilbiie et al. (2005), Jaimovich (2007), and Jaimovich and Max (2008) among others.

There is a general consensus regarding the relevance of TFP shocks for explaining business cycle fluctuations. But what share of the explanation can be attributed to innovation shocks? Justiniano et al. (2010) report an interesting study of the driving forces of economic fluctuations in a new neoclassical model and estimates it with US data. They show that investment shocks account for between 50 and 60% of the variance of output and labour at business cycle frequencies and more than 80% of investment variance. These effects are much larger than those of the neutral technology shocks (TFP shocks), which account for 25% of the movements in output and consumption and for 10% of the variance of labour.

Section two presents the set-up of a financially integrated world and highlights the differences with a financial autarky and a closed economy. The model has no closed-form solution; therefore Section three presents the results of the quantitative exercise. Section four concludes.

II. The Model

The world consists of two symmetric countries, denoted by H (Home) and F (Foreign) and an endogenous size of the mass of tradable varieties. There is no capital accumulation but a cost to enter the market with a lag of one period. This feature reflects the empirical finding in Bergin and Corsetti (2008) that entry does not appear to respond contemporaneously to innovations, but rather that the response reaches its maximum after one year.[3] For simplicity, this fixed cost of entry is assumed to be repaid each period, as in Bergin and Corsetti (2008), Kim (2004) and Devereux et al. (1996).

In Justiniano et al. (2010) investment (or innovation) shocks are a source of exogenous variation in the efficiency with which the final goods can be transformed into physical capital, and thus, into tomorrow’s capital input. Similarly, here, a variation in the cost of entry implies a change in the efficiency with which the final goods are transformed into a new firm able to produce a new variety (physical capital).

Bergin and Corsetti (2008) consider the entry cost as the unique physical capital of the economy, as I do here. However, they offer an extension of their model in which standard capital is added to the production function. They find that aggregate variables respond in the same way as in their basic setup with small-scale effects.

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[2] See, for example, Hummels and Klenow (2005) for an empirical analysis.

[3] The empirical result in Bergin and Corsetti (2008) refers to a reduction in the cost of entry caused by a monetary shock. The authors show that the variability in an entry cost with love of variety (such as one used in this paper) generates per se a persistent response of entry that allows more complex dynamics in entry to be captured , bringing the model much closer to the actual dynamics.

To fulfil the aims of this paper, however, the entry-cost capital specification is necessary. This represents the driving force of the endogenous entry of firms[4] and it generates more realistic persistence in the dynamics of the extensive margin.

Justiniano et al. (2011) argue that investment shocks might stem from technological factors specific to the production of investment goods (a sector-specific shock), as in Greenwood et al. (1997), or from disturbances to the process by which these investment goods are turned into productive capital. Either of these interpretations is valid in the present model.

Firms and agents are homogeneous within the countries. Each monopolistic firm produces a differentiated variety and sets prices flexibly in order to maximise profits.

Notice that firms must operate in a monopolistic context to allow for positive profits that attract their entry into a market. Moreover, since it is assumed that households demand any variety supplied in the market (that is, they have 'love of variety'), a new firm will never find it profitable to produce a variety already being produced by other firms and so will opt to introduce a new one.

The following set-up describes a benchmark Home country, which is connected with a Foreign country via trade in goods and assets. Differences with the autarkic and the financial autarky scenarios are highlighted at the end of the section. The autarkic or closed economy is completely isolated from the rest of the world and, therefore, it does not consume Foreign goods or export at all and its households are restricted in their investment choices to just domestic assets. The financial autarky is also restricted to the domestic capital market as regards savings and investment; however, households can consume Foreign goods and its firms do sell on the world market. Consequently, a balanced trade balance must be imposed: countries cannot incur external trade imbalances because they cannot compensate for them with external deficits or surpluses in investment.

Households

Countries are populated by a unit mass of households that maximismaximise utility, $U=\sum_{t=0}^{\infty}\beta^t\left(\ln C_t+\kappa\ln\left(N-\ell_t\right)\right)$, where $0<\beta<1$ is the discount factor; C_t, the basket of consumption; κ, the disutility of labour; N, the total endowment of time a household can allocate between leisure and work; and ℓ_t, the elastic household's labour supply.[5] The consumption basket is $C_t=C_{H,t}^{\gamma}C_{F,t}^{1-\gamma}$, where $0<\gamma<1$ and

[4] See Bilbiie et al. (2007) for a detailed discussion on the need for sunk entry costs in this context.

[5] Often, household's decision variables including, for instance, elastic labour supply are indexed for individuals, $\ell(j)$, ... However, this is not necessary here because I assume a mass 1 of households or total population, $L=1$.

$$C_{H,t} = \left(\int_0^{n_t} c_t(h)^{1-\frac{1}{\sigma}} dh\right)^{\frac{\sigma}{\sigma-1}}; C_{F,t} = \left(\int_0^{n_t^*} c_t(f)^{1-\frac{1}{\sigma}} df\right)^{\frac{\sigma}{\sigma-1}}. \quad [1]$$

$n(n^*)$ is the size of the mass of varieties $h(f)$ produced in the Home (Foreign) country. For simplicity, I assume identical elasticity of substitution, $\sigma > 1$ in both countries. In the financially integrated scenario, households finance the creation of firms in both countries. To construct her investment portfolio, the household purchases a fraction $\lambda_{F,t+1}(\lambda_{H,t+1})$ of the shares issued by Foreign (Home) firms that will start producing in the next period. The household can cover her consumption expenditure and investment with the income she receives from her labour, from the bonds bought in the previous period and their returns, and from dividends of currently active firms. The dividends are proportional to her portfolio allocation: $\lambda_{H,t}$, $\lambda_{F,t}$. The budget constraint in nominal terms is

$$B_{t+1} + \lambda_{H,t+1} \int_0^{n_{t+1}} q_t(h)dh + e_t \lambda_{F,t+1} \int_0^{n_{t+1}^*} q_t^*(f)df +$$
$$+ \int_0^{n_t} p_t(h)c_t(h)dh + \int_0^{n_t^*} p_t(f)c_t(f)df =$$
$$= \lambda_{H,t} \int_0^{n_t} \pi_t(h)dh + e_t \lambda_{F,t} \int_0^{n_t^*} \pi_t^*(f)df + w_t \ell_t + (1+i_t)B_t. \quad [2]$$

An initial investment is needed for a new firm to start producing at Home (Abroad), $q_t(h)$ ($q_t^*(f)$). $\pi_t(h)$ ($\pi_t^*(f)$) are the profits of a single Home (Foreign) firm in Home (Foreign) currency; e_t is the nominal exchange rate and the law of one price holds, $p_t(h) = e_t p_t^*(h)$); $c_t(h)$ is the domestic demand for good h; w_t, the wage; B_t, the international risk-free bond; lastly, γ indicates consumption preferences.

Firms

A continuum of n (n^*) firms in the Home (Foreign) country sell their products in both markets. To produce a home variety at time $t+1$, entrepreneurs must incur a start-up cost of $q_t(h) = P_{k,t} K_t$ at time t. This cost is financed by issuing equities in the international stock market. Firms are fully depreciated after one period of production. K_t, the size of which is randomly determined every period, is a composite good containing both Home and Foreign varieties:

$$K_t = K_{H,t}^{\delta} K_{F,t}^{(1-\delta)}, \quad [3]$$

where $K_{H,t}$ ($K_{F,t}$) is the basket of final goods used for capital by the Home (Foreign). The lower the $K_t(K_t^*)$ the more efficient is the Home (Foreign) country in the creation of new firms or varieties. δ describes the preferences for capital varieties. $P_{k,t}$ is the price index for basket K_t and

$$K_{H,t} = \left(\int_{h=0}^{n_t} k_t(h)^{1-\frac{1}{\sigma}} dh\right)^{\frac{\sigma}{\sigma-1}} ; K_{F,t} = \left(\int_{f=0}^{n_t^*} k_t(f)^{1-\frac{1}{\sigma}} df\right)^{\frac{\sigma}{\sigma-1}}, \qquad [4]$$

where $k_t(h)$ is the demand for the final good h from new entrants to build their plants. The cost for creating any of the firms that will be operative next period at Home is the same for all of them. Therefore, total investment at Home made by households all over the world is $I_{H,t} = \int_0^{n_{t+1}} q_t(h) dh = n_{t+1} q_t(h)$. The second equality is true thanks to the homogeneity of every firm involved in the process of creation. Notice that δ and γ are measures of the degree of trade openness. Therefore, $\delta = 1$ for the closed economy.

Once created, every firm produces a differentiated variety with homogeneous technology which requires only labour, $y_t(h) = A_{H,t}\ell_t(h)^{\theta}$. $\theta < 1$ indicates decreasing returns to scale. $y_t(h)$ is the production of one firm; $p_t(h)$, the price of variety h and $\ell_t(h)$, labour demand for good h.

Equilibrium

Households

Households maximise utility subject to the budget constraint with respect to labour, consumption, B_{t+1}, $\lambda_{H,t+1}$ and $\lambda_{F,t+1}$. Notice that the optimal investment allocation made by any homogeneous household in this economy is identical to the investment allocation that a global mutual fund would choose. This is true because households are well informed and there are no transaction costs. A mutual fund would improve efficiency in those cases in which the size of the investor is relevant, for example, when commissions and transaction costs exist and are higher for individuals than they are for the mutual fund or when transaction costs differ for investments at Home (cheaper) and abroad. In this set-up, however, households can allocate investment in the most efficient way. Indeed, a household constructs a global portfolio endogenously, by choosing $\lambda_{H,t+1}$ and $\lambda_{F,t+1}$ depending on expected profits, which are identical for each country. This is exactly what a mutual fund would do. The first order conditions are

$$\frac{w_t}{P_t C_t} = \frac{\kappa}{N - \ell_t(j)}, \quad [5]$$

$$C_{H,t} = \gamma \frac{P_t C_t}{P_{H,t}}; \; C_{F,t} = (1-\gamma)\frac{P_t C_t}{P_{F,t}}; \quad [6]$$

$$c_t(h) = C_{H,t}\left(\frac{p_t(h)}{P_{H,t}}\right)^{-\sigma}; \; c_t(f) = C_{F,t}\left(\frac{p_t(f)}{P_{F,t}}\right)^{-\sigma}; \quad [7]$$

$$B_{t+1}: \; \frac{1}{P_t C_t} = \beta(1+i_t)E_t \frac{1}{P_{t+1}C_{t+1}}; \quad [8]$$

$$q_{H,t} = E_t Q_{t,t+1}\Pi_{H,t+1}; \quad [9]$$

$$e_t q^*_{F,t} = E_t Q^*_{t,t+1} e_{t+1}\Pi^*_{F,t+1}; \quad [10]$$

where $Q_{t,t+1}$ is the discount factor of future dividends, E_t is the expectations operator and $q_{H,t}$ ($q^*_{F,t}$) is the country aggregate of $q_t(h)$ ($q^*_t(f)$). Equations [9] and [**10**] are the free-entry conditions for new firms. Firms enter the market whilst the initial fixed cost is lower or equal to the expected profits. $\Pi_{H,t}$ are the aggregate profits of domestic firms. The rest of the FOCs are standard. Equation [5] provides the endogenous supply of labour in hours; equation [**6**] shows the allocation of consumption expenditure between home- and foreign-produced goods; equation [8] is the Euler equation. Moreover,

$$Q_{t,t+1} = \frac{1}{1+i_t} = \beta E_t\left(\frac{P_t C_t}{P_{t+1}C_{t+1}}\right) \quad [11]$$

is the intertemporal rate of substitution between consumption in period t and $t+1$. The welfare-based price index is

$$P_t = \frac{P^{\gamma}_{H,t} P^{1-\gamma}_{F,t}}{\Gamma} \quad [12]$$

where $\Gamma = \gamma^{\gamma}(1-\gamma)^{1-\gamma}$. Foreign households solve an analogous problem with symmetric preferences.

Firms

During the **creation of varieties**, Home firms choose the demand for each capital good, $k_t(h)$ and $k_t(f)$ and the amount of labour by minimising costs subject to technological constraints. They solve the following three minimisation problems to choose the demand for $k_t(h)$, $k_t(f)$ and $\ell_t(h)$:

$$\min_{k_t(h)} \int_0^{n_t} p_t(h) k_t(h) dh - \zeta_t \left(\left(\int^{n_t} k_t(h)^{1-\frac{1}{\sigma}} dh \right)^{\frac{\sigma}{\sigma-1}} - K_{H,t} \right), \quad [13]$$

which produces

$$k_t(h) = \left(\frac{p_t(h)}{P_{H,t}} \right)^{-\sigma} K_{H,t}; \quad [14]$$

$$\min_{k_t(f)} \int_0^{n_t^*} p_t(f) k_t(f) dh - \zeta_t^* \left(\left(\int^{n_t^*} k_t(f)^{1-\frac{1}{\sigma}} df \right)^{\frac{\sigma}{\sigma-1}} - K_{F,t} \right) \quad [15]$$

which yields

$$k_t(f) = \left(\frac{p_t(f)}{P_{F,t}} \right)^{-\sigma} K_{F,t}; \quad [16]$$

and

$$\min w_t \ell_t(h), \quad [17]$$

subject to the technology constraint. The first order condition is,

$$\varphi_t = \frac{w_t}{\theta A_{H,t}} \ell_t(h)^{1-\theta}. \quad [18]$$

The shadow prices, represented by the Lagrange multipliers are, respectively, $\zeta_t = P_{H,t} = n_t^{\frac{1}{1-\sigma}} p_t(h)$, $\zeta_t^* = P_{F,t}$ and φ_t, which represents the marginal cost. Therefore, the optimal baskets of Home and Foreign capital goods are $K_{H,t} = \delta \frac{P_{k,t} K_t}{P_{H,t}}$ and $K_{F,t} = (1-\delta) \frac{P_{k,t} K_t}{P_{F,t}}$.

Once operative, firms maximise profits subject to the technology restriction and to demands from households and from future firms:

$$\max_{p_t(h)} p_t(h) Y_t(h) - w_t \ell_t(h). \quad [19]$$

Thus, the optimal price consists of a constant mark-up over marginal costs which depends on the level of production due to the nonlinear technology,

$$p_t(h) = \frac{\sigma}{\sigma-1}\frac{1}{\theta}\frac{w_t}{A_{H,t}^{\frac{1}{\theta}}}Y_t(h)^{\frac{1}{\theta}-1}. \quad [20]$$

The real exchange rate for this economy is $RER_t = \frac{P_t}{e_t P_t^*} = \left(\frac{P_{F,t}}{P_{H,t}}\right)^{1-2\gamma}$ and terms of trade, $TOT = \frac{P_H^*}{P_F}$. Since prices are flexible and firms do not discriminate prices for different countries, the results in this section are true for every scenario considered.

Market clearing

Market clearing in the open economy requires:

$$c_t(h)+c_t^*(h)+n_{t+1}k_t(h)+n_{t+1}^*k_t^*(h)=Y_t(h); \quad [21]$$

$$c_t(f)+c_t^*(f)+n_{t+1}k_t(f)+n_{t+1}^*k_t^*(f)=Y_t(f). \quad [22]$$

$$n_t\ell_t(h) = \ell_t L_t;\; n_t^*\ell_t^*(f) = \ell_t^* L_t^*. \quad [23]$$

$$B_t = -B_t^*;\; \lambda_{H,t} = 1-\lambda_{H,t}^*;\; \lambda_{F,t} = 1-\lambda_{F,t}^*. \quad [24]$$

Moreover, households in the financially integrated economy choose portfolios to obtain $P_t C_t = e_t P_t^* C_t^*$.

Financial Autarky

In the case of financial autarky, households limit their investment to domestic firms, being $\lambda_H = 1$ and $\lambda_F = 0 = B$ at Home. Therefore, equation [**10**] does not apply since $\lambda_{F,t+1} = 0$.
Since countries cannot incur any debts, one has to impose a balanced trade account, $c_t^*(h)p_t(h)n_t = c_t(f)p_t(f)n_t^*$.
The foreign country is completely symmetric.

Closed Economy

In the case of a closed economy, households limit their investment to domestic firms, as in the financial autarky, being $\lambda_H = 1$ and $\lambda_F = 0 = B$ at Home. Hence, equation [**10**] does not apply since $\lambda_{F,t+1} = 0$.
In addition to this, they consume domestic goods exclusively, so one has to impose $\gamma = 1$. This implies that $C_{H,t} = C_t$ and $P_t = P_{H,t}$. Therefore, equation [7] becomes $c_t(h) = C_t\left(\frac{p_t(h)}{P_t}\right)^{-\sigma}$. $c_t(f)$, $C_{F,t}$ are zero.
In order to clear markets, Home and Foreign autarkic economies require, respectively,

$$c_t(h)+n_{t+1}k_t(h)=Y_t(h); \text{ [25]}$$

$$n_t\ell_t(h)=\ell_t L . \text{ [26]}$$

$$c_t(f)+n_{t+1}k_t(f)=Y_t(f); \text{ [27]}$$

$$n_t^*\ell_t^*(f)=\ell_t^* L^* . \text{ [28]}$$

The foreign country is completely symmetric.

The model cannot be solved in closed-form. For this reason, in the next section I develop a numerical solution for each of the three scenarios and analyse differences in their macroeconomic volatility.

III. Quantitative Exercise

The equilibrium for each of the three scenarios is computed numerically using a first-order approximation with the Schmitt-Grohe algorithm. The consumer price index, *P*, is normalised to one. Therefore, variables are in units of baskets of consumption and prices are relative to *P*. The quantitative exercise addresses two points: first, it analyses the macroeconomic consequences of shocks on the technology of creation and on the technology of production. Second, it studies the relative change in macroeconomic volatilities suffered by countries that open up their borders to trade and to capital flows.
The shock processes for Home are defined as follows:

$$A_{H,t} = \phi_t A_{H,t-1} + (1-\phi_t)A_{H,0} + \eta_t; \quad \text{[29]}$$

$$K_t = \phi_{K,t} K_{t-1} + (1-\phi_{Kt})K_0 + \eta_{K,t}, \quad \text{[30]}$$

where η and η_k are independent and identically distributed (iid) shocks and ϕ and ϕ_K are their persistence. When no shock has occurred in the past, $A_{H,t} = A_{H,0}$ and $K_t = K_0$, which are set to 1. Notice that, K is a composite good made up exclusively of final goods. These final goods are produced with technologies A_H and A_F. Therefore, any disturbance affecting A_H or A_F affects the cost of both consumption and capital goods. For this reason I refer to η as the TFP shock. The baseline parameterisation is summarised in Table 1.

Definition	**Notation**	**Value**
Share of domestic goods in consumption	γ	0.67
Share of domestic goods in capital	δ	0.85
Discount factor	β	0.99
Technology	θ	0.66

Intratemporal elasticity of substitution	σ	6
Disutility of labour	κ	1.75
Total population	$L = L^*$	1
Persistence of shock η	$\phi = \phi^*$	0.95
Persistence of shock η_K	$\phi_K = \phi_K^*$	0.95
Total endowment of time	N	1

Table 1: Baseline parameterization

The model has only two sectors, the final goods sector and the capital goods sector. To measure the width of the cross-border channel of transmission of shocks via trade, one has to account for the overall degree of openness in trade. Here, I follow Heathcote and Perri (2007) in undertaking its computation. In common with the approach adopted here, they use a Cobb-Douglas aggregator of Domestic and Foreign goods to design the basket of consumption. They use the weighted average of imports and exports over GDP to find their $1-\gamma$, by computing $\frac{M+X}{2GDP}$, where weights are country-shares in total GDP of the group of countries considered. They find $1-\gamma = 0.34$. However, the present model captures two channels of transmission via trade. Hence, I subtract imports and exports of capital goods to compute the appropriate $1-\gamma$. Shocks are also transmitted abroad because firms use Foreign capital goods to set-up new plants. In the model, capital is built period by period to create new varieties and it is not accumulated. The parameter δ belongs to the technology of creation of this capital. Hence, the most suitable measure of $1-\delta$ in the data is the share of imports in gross fixed capital formation. The trade share in capital goods is defined as

$$1 - \delta = \frac{M_K}{GFCF}, \quad [31]$$

where M_K is the GDP-weighted average cost of imports in capital goods, and $GFCF$ is the gross fixed capital formation. Both the imports content of $GFCF$ and $GFCF$ itself are drawn from the OECD database. The OECD has collected data on the imports content of gross fixed capital formation for 1995, 2000 and 2005.[6] I use 2005 weighted average data for the 12 countries in the European Union which report this information (that is, Austria, Belgium, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain and the United Kingdom) and find that $\gamma = 0.67$ and $\delta = 0.85$. The latter value is in line with the figure reported by Eaton and Kortum (2001), who show that home bias in capital goods is, on average, larger than that in consumption goods.[7] The discount factor β

[6] At the time of writing, no data are available for 2010. All countries reporting data for this series to the OECD have an import share that is below fifty percent of their capital formation.

[7] A large part of the literature agrees that physical capital is mainly bought or built domestically. First, construction (of the plants and of some equipment installations) is almost entirely local, and it represents a large proportion of the total set-up costs; second, equipment trade is tied to costs arising from overseas marketing (transportation, tariffs and non-tariff barriers, distribution in foreign markets, adaptations to foreign conditions and standards, installation in Foreign production facilities, the need to train Foreign workers to use the equipment and the provision of parts, maintenance and customer service from abroad). The home bias in capital reported here is larger than that found in Eaton and Kortum (2001) as the latter do

is set to match an annualised interest rate of 4%. The elasticity of substitution between varieties σ is chosen as having a mark-up of 20%, which is the business cycle value generally found for advanced economies.[8] κ is set to produce a steady state value of time devoted to work equal to $1/3$. θ has the standard value 0.66 as in Galí (2008). I assume a persistence of shocks of 0.95 and set the mass of households, $L = L^* = 1$. As such, countries are completely symmetric.

Transmission of shocks

Figure 1 and Figure 2 show the deviations from the steady state following a 1% increase in η and a 1% decrease in η_K in the Home country, respectively, that is, a positive shock in the productivity of production and in the productivity of creation of new varieties. Both figures depict the three economic scenarios considered. Variables are in logs and the zero-line is added to indicate the steady state.

The financial autarky and the financially integrated economy are assumed to have the same degree of openness in goods trade: $\gamma = 0.67$ and $\delta = 0.85$, which are the average levels found for the twelve aforementioned EU countries in 2005.

The comparison between the closed economy and the financial autarky scenarios sheds light on the consequences of opening a country up to trade for international transmission of shocks, while the comparison between financial autarky and financial integration shows the consequences of allowing capital markets to integrate. These differences are analysed in the following two subsections for deviations of η and of η_K from zero.

TFP shocks, η

For the country suffering a change in η, real variables behave in similar ways regardless of whether the country is a closed economy or a financial autarky. Any differences are limited to changes in the magnitude of the response. Immediately after the shock, the intensive margin (that is, production per firm), $y(h)$, increases. The extensive margin, n (the mass of operating firms and varieties), cannot react due to the necessary time-to-build. Firms are created using final goods, which are now cheaper to produce. Therefore, new firm creation becomes cheaper too. Households, aware of the persistence of the shock and now wealthier thanks to a higher output, save and invest more to take advantage of high productivity. From $t = 1$, n increases at the expense of the intensive margin.

When the country trades, the trading partner country receives some of the effects of the shock. The channel of transmission is the Terms Of Trade (TOT). The reduction in Home prices makes imports relatively more expensive for a country that seeks to balance its trade every period; in other words, TOT deteriorates for Home. Therefore, consumption at Home does not as benefit as much from the shock as it does in the closed economy. The Foreign country benefits from cheaper prices for its imports and can increase consumption, which pushes output up. However, the creation of new firms is now relatively more expensive compared to the cost at Home and so households decide to create fewer firms. The

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not include the costs derived from construction.

[8] See Bergin et al. (2007).

transmission is positive: a positive shock in one country generates improvements in consumption and output in the other.

The differences between the financial autarky and the financially integrated economy in Figure 1 illustrate the way in which TFP shocks are transmitted when a country opens up its capital market to the world. Compared to households in a financial autarky, those in a financially integrated world own domestic and Foreign equities issued by firms. When a country receives a positive shock, the households in the Foreign country can take advantage by investing more in the relatively more productive country. As a consequence, a share of the profits is also sent abroad.

The financially integrated and the financially autarkic economies respond in a similar manner to a positive shock in Home productivity. TOT deteriorates more markedly in the former case. However, countries are not forced to maintain a trade balance, which pushes Foreign demand towards cheaper Home goods and generates larger output and consumption at Home. Both variables increase more than in a financial autarky because the magnitude of this substitution effect in favour of Home goods is greater than the consequences TOT deterioration has on them. However, this substitution effect damages Foreign output, although Foreign households still enjoy larger consumption when the shock occurs. Foreign consumption is larger than in the financial autarky thanks to the participation of Foreign households in Home firms and the possibility of maintaining a temporary trade imbalance.

Notice that the new international linkage, via capital markets, permits a larger response of the intensive margin after a shock on TFP, i.e., $y(h)$ increases more than it does in the financial autarky because agents can allocate savings more efficiently.

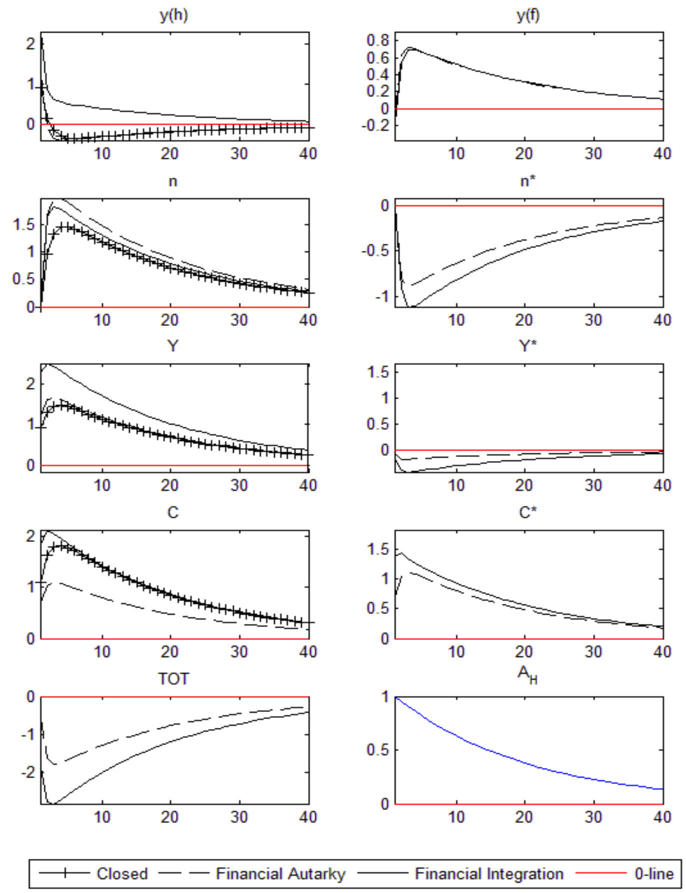

Figure 1: 1% deviation in A_H. Three economic scenarios.

Innovation shocks, η_k

Figure 2 shows the impulse responses after a 1% negative deviation in η_K, i.e., a reduction in the cost of innovation or creation of new firms and varieties. The shock generates an upsurge in the creation of new firms, regardless of the economic scenario. However, since production remains as costly as before the shock, production per firm decreases with competition. When the country is opened up to trade, it benefits from Foreign demand, which is partially redirected towards the most efficient country. First, prices decline thanks to increased competition resulting from a larger mass of operative firms. Second, Domestic and Foreign households alike consequently consume more Home goods. This leads to the start up of more firms, which reduces the price index of Home goods further and makes new firm creation even cheaper. As a result, in the financial autarky, the total investment needed to generate the larger mass of firms just after the temporary shock is lower than that in the steady state value. Since the subsequent effect of Foreign demand redirection cannot occur in a closed economy, total investment in the latter scenario is larger after the shock. Indeed, the aggregate decline in production in the intensive margin, due to lower demand per variety and lower quantities required to create firms, is larger than the aggregate increase in production in the extensive margin, which causes a reduction in economic growth. However, consumers are better off thanks to higher consumption. Notice that the transmission to the Foreign country is also positive in consumption, although more modest than after a η shock, and in output per firm. As a consequence, households in both countries, who redirect part of the demand towards Home goods, benefit less from the reduction in prices and have less income left to satisfy the demand for Foreign goods. The result is a temporary reduction in Y^*.

The differences between financial autarky and financial integration are, as before, seen solely in the magnitude of variable responses in the first few periods after the shock. The explanations previously given for changes in η are also valid here, although differences in Y, C and $y(h)$ are more modest because a change in η_K does not have the same power of transmission over the economy as a TFP shock does. Moreover, recall that trade openness in capital goods is low with $\delta = 0.85$. Notice that the financially integrated economy suffers a more modest deterioration in TOT compared to that suffered by the financial autarky. With financial integration, part of the domestic profits leave the country to be spent mainly in Foreign goods, which serves to cushion in part of the fall in domestic prices. Consequently, the substitution effect in demand is smaller. This is the reason why Foreign households benefit less in terms of C^*, and n^* is not so severely damaged.

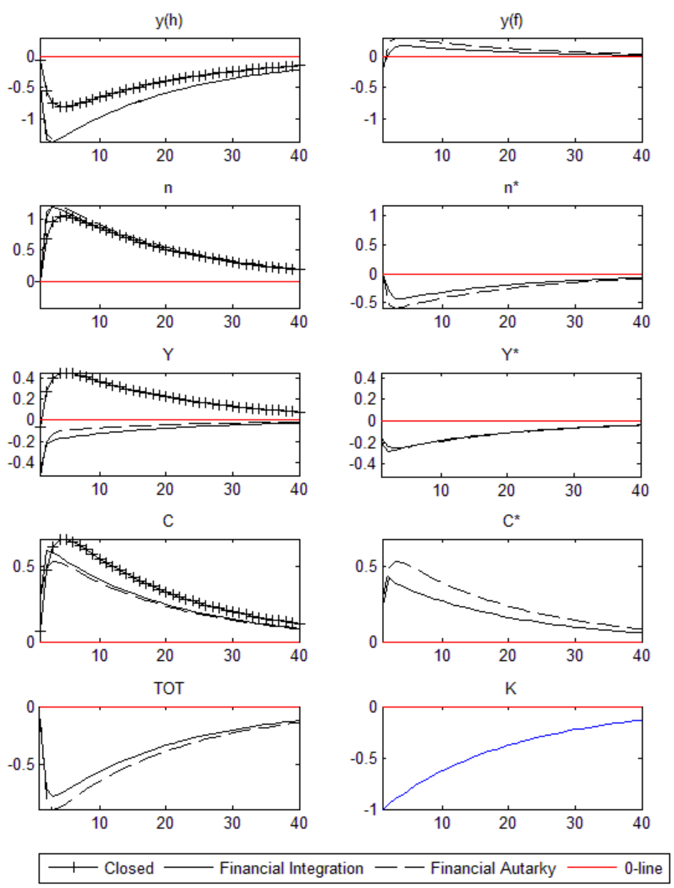

Figure 2: 1% deviation in K. Three economic scenarios.

Changes in macroeconomic volatility

Although the model allows for different degrees of trade interaction in the capital and goods markets, the relative volatility outcomes are determined by the overall openness in trade. The reason for this lies in the fact that the transmission of real shocks to the macroeconomic variables occurs via TOT and its adjustments feed back into the process time and again and between markets. Clearly, since capital goods and consumption goods have different sources of demand (consumers and new firms) and, as a consequence, different roles in international transmission, TOT changes differ in magnitude depending on δ and γ. However, TOT incorporates these differences and only by considering the overall degree of openness can we account for the full effect of any shock. Accordingly, this subsection analyses relative volatility for different degrees of total openness in goods trade (that is, δ is assumed to be equal to γ).

The aim of the section is to observe how aggregate uncertainty, measured in terms of the standard deviations of certain macroeconomic variables, evolves. I analyse the way in which this evolution is dependent on two factors: first, on the shares of Foreign goods that countries incorporate in their baskets of consumption and of physical capital. As a theoretical exercise, I consider a wide range of possible values for $\gamma = \delta$, regardless of the fact that countries may never reach such extreme shares of Foreign goods in their baskets of consumption or capital goods.[9] Second, I study how volatility evolves depending on whether a country trades in assets or not. The appendix presents a closer examination of C/Y volatility by considering the case in which goods markets open internationally one by one.[10]

Figure 3 presents the results for the evolution of conditional macroeconomic volatilities (in standard deviations) over trade openness, following TFP (η) and innovation (η_K) shocks occurring at Home, where $\gamma = \delta$ and a high value indicates a low degree of openness. As such, Figure 3 reflects the increase or reduction in aggregate volatility experienced by a country that opens up its borders. It focuses specifically on the sources of turbulence that would have already been present when the country was isolated from the world, in other words, on the shocks that occurred within its borders.[11]

If the countries were considered to be different, it would be interesting to analyse the effects on aggregate volatility of TFP and innovation shocks occurring, simultaneously, in both countries. The asymmetric transmission might have provided interesting results. However, this lies beyond the scope of the present study. In my set-up, transmission is fully symmetric and simultaneous shocks in the Home and Foreign countries leave their respective volatilities as if they were autarkies, regardless of the degree of openness. Since

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[9] However, countries present very different positions in the amount of Foreign goods they incorporate, especially in their baskets of consumption. For instance, in line with the definitions of trade openness used in this paper, Ireland has a $\gamma = 0.26$ and a $\delta = 0.83$, whereas Greece has a $\gamma = 0.76$ and a $\delta = 0.79$.

[10] See Figure 5 in the appendix.

[11] The appendix includes Figure 4, which shows the consequences for Home aggregate volatility of shocks on Foreign TFP (η^*) and on Foreign innovation efficiency (η_k^*). Turbulence from abroad represent a new source of volatility for a country opening up its borders.

countries are symmetric in every respect, parameterisation is also symmetric. The correlations between shocks across types (of turburlence) and countries are assumed to be zero as in Evans and Hnatkovska (2007).

Shifting from a closed economy to a Financial Autarky (FA) that trades in goods reduces the volatility of consumption σ_C, the mass of firms σ_n and the firm size $\sigma_{\ell(h)}$. As such, trade integration boosts the international share of the risk originated by country shocks through TOT (as in Cavallo's (2008) empirical analysis). However, some differences arise when comparing the sources of the shocks: the conditional volatility of consumption-to-output ($\sigma_{C/Y}$) is higher under an FA but decreasing (nonlinear) in openness after a TFP (innovation) shock.[12] [13] Let us focus on η first. For extreme values of γ, the possibilities of risk-sharing via TOT are small. For very low values of γ, the bulk of Home production is sold abroad. Hence, when a shock occurs at Home, very little changes for Home households. Foreign demand for Home goods increases Y, which in turn increases Home consumption . Hence, C/Y does not change greatly. Rather, for very high values of γ, the same shock produces major adjustments in the purchasing power of the Home households, which now consume a larger share of the cheaper goods, exacerbating C/Y volatility.

When the shock is in TFP, firms achieve greater efficiency in the production of final goods, while their innovation, which requires these final goods, also becomes cheaper. By contrast, when the shock is in K, innovation gains in efficiency whereas the final goods used in creation do not. This is the reason for the lower conditional volatility of C/Y for low levels of openness. As openness increases, the volatility generated by TFP shocks can be diversified via TOT, as explained above. Instead, the volatility derived from a deviation of η_K is not transmitted as much due to its reduced impact on P_H and conditional $\sigma_{C/Y}$ increases.

Now, compare a financial autarky with a Financially Integrated economy (FI). For the same degree of trade openness, and regardless of the shock, output (as Buch et al. (2005) show) is more volatile in the FI scenario. The FI economy suffers from higher volatilities in consumption after TFP shocks, whilst innovation shocks generate nonlinear patterns in relative consumption volatility (in other words, for high values of γ, σ_C is larger in FI than it is in FA, whereas the opposite is true for low values of γ). Consequently,there are also changes in the relative conditional volatility of $\sigma_{C/Y}$ depending on the degree of trade openness. A positive TFP shock makes the demand for Home goods and the creation of

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[12] In the closed economy, $\frac{C_t}{Y_t} = 1 - \frac{I_t}{Y_t}$ and savings equal investment, therefore, $\sigma_{C/Y} = \sigma_{I/Y}$. Moreover, due to the utility specification, which is a monotonic transformation of a Cobb-Douglas function, C/Y is constant. Hence, $\sigma_{C/Y} = 0$. This is no longer true for the open economy where Y and C include exports and imports and, for the financially integrated economy, domestic savings are no longer equal to domestic investment.

[13] Indeed, the constant consumption-output ratio in the closed economy is the result of the unitary elasticity of intertemporal substitution (EIS) between goods assumed in the model throughout the three scenarios. A non-unitary EIS would also produce some fluctuation in the closed economy. However, this would also affect the open economy and would not change relative volatilities. There is a large literature discussing the adequate assumptions for EIS for use in macroeconomic models of the kind presented here. Guvenen (2006) lends support to a unitary EIS when the scope of the analysis is the understanding of aggregate fluctuations.

firms at Home more attractive. This modifies world investment, exploiting the higher efficiency of creation to its maximum, while price indices become more reactive. These two effects increase σ_Y. The first requires larger adjustments in the demand for Home goods to create more firms, the second increases the households' demand for consumption goods. When γ is high, Home households that pay lower prices for a large share of their consumption goods and receive most of the Home profits benefit most. Hence, consumption moves with output and $\sigma_{C/Y}$ is below its FA counterfactual. As the country opens up, a larger share of the instability caused by the shock is transmitted to the Foreign country via TOT and profits. Therefore, output continues to react considerably whereas consumption at Home benefits less. Now $\sigma_{C/Y}$ is above that of the FA case.[14]

Relative conditional $\sigma_{C/Y}$ goes in the opposite direction after a η_K shock. As discussed above, this shock causes lower adjustments in prices compared to those resulting from TFP shocks. When γ is high, in the first period after the innovation shock output decreases (less is needed to create firms) whilst consumption increases (although not as much as in FA, because of profit sharing and the lower adjustment of prices), causing large movements in $\frac{C}{Y}$. For low γ, more Foreign goods are used for innovation. Hence, the innovation shock releases less Home production, stabilizing output. The consumption adjustment is also more modest due to profit sharing. Together, these offer lower $\sigma_{C/Y}$.

[14] The threshold is somewhere above $\gamma = 0.5$ due to the symmetry between countries and the nature of the idiosyncratic shocks. Shocks generate exchange rate depreciation which may improve the Home situation when home bias in consumption exists and, therefore, the need for imports is low while the country maintains a low level of exports.

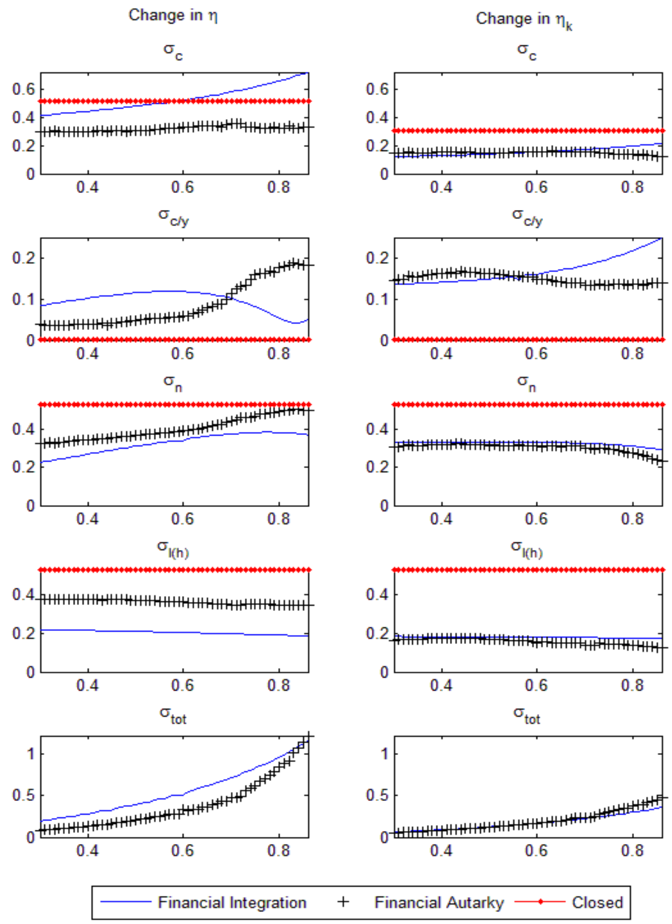

Figure 3: Conditional volatility over trade openness.

Note: Plots show the standard deviations for aggregate variables after deviations of η and η_K from zero. The abscissa represents different levels of $\gamma = \delta$. Therefore, total openness to trade reduces to the right. The line labelled closed is added for comparative reasons and represents the closed economy, where $\gamma = \delta = 1$.

IV. Conclusion

This paper has explored how macroeconomic volatility change when the economy opens up its borders, first to the goods market and subsequently to the financial markets. It addresses this issue using a two-country micro-founded model and two real shocks: one on innovation, the other on total factor productivity.

The main results can be summed up as follows: first, financial integration and trade openness do play a role in macroeconomic volatilities. Changes in the capability of TOT and profit-sharing to transmit shocks, depending on the degree of integration in the respective international connections, may explain the empirical nonlinearity in consumption-to-output volatility. Second, conditional on innovation shocks, any kind of integration reduces macroeconomic volatilities for an initially closed economy. However, whether financial integration will reduce consumption volatility for a financial autarky depends on the degree of trade openness. The greater the degree of openness attained by a country the more likely financial integration is to help Home reduce the conditional volatility of its consumption-to-output ratio. Third, with financial integration, the model predicts less (greater) instability of firm size and less (greater) instability of the extensive margin (size of the mass of firms) after a total factor productivity (innovation) shock, compared to the situation in a financial autarky. This is an interesting result and merits further empirical examination.

Clearly, integration means having to open one's borders to new linkages with the rest of the world. Such a decision has obvious benefits but it can also be the source of uncertainties. It is crucial that authorities are aware of how their economies will be affected. The model presented here sheds some light on the mechanism underpinning changes in the level of aggregate uncertainty.

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Appendix

Home aggregate volatility after Foreign shocks

Figure 4 shows the changes in Home aggregate volatility attributable to Foreign shocks. The first column reflects the consequences of a foreign TFP shock and the second column, those of a shock on the efficiency of foreign innovation.

The closed economy is represented by the zero-line in each subplot, since none of these shocks could have been transmitted to a Home autarky. Moreover, recall that a lower $\delta = \gamma$ (that is, moving towards the left edge of the abscissas) means that a larger share of the basket of consumption and of the investment goods is composed of foreign goods.

In general, Home aggregate volatilities are more modest in response to Foreign shocks than they are to Home shocks and the evolution with openness is as expected once Figure 3 is clear. For instance, the first row of Figure 4 shows that consumption volatility at Home increases with the share of Foreign goods in Home baskets, irrespective of the degree of financial integration and the source of the shock. In other words, Foreign shocks cross borders more easily as the weight of Foreign goods increases in Home baskets. As in the case with Home shocks, σ_c is larger with financial integration.

Notice that the nonlinearity of relative $\sigma_{C/Y}$ with respect to financial integration is still present, although more modest, after a Foreign innovation shock. By contrast, the nonlinearity disappears after Foreign TFP shocks (in other words, unlike in the case of Home TFP shocks, $\sigma_{C/Y}$ is larger in FI than in FA irrespective of the degree of trade openness).

Home output volatility decreases for both economic scenarios after a Foreign TFP shock when compared to a Home TFP shock, but the reduction is more marked in the FI economy. Instead, Home consumption volatility is only slightly below its level after a shock at Home. Therefore, with financial integration, the volatility transmitted to output from abroad is much lower than that transmitted to consumption. Consequently, $\sigma_{C/Y}$ is larger compared to levels in Figure 3. Recall from Figure 1 that a TFP shock in one country causes a positive response in consumption and a negative response in aggregate output in the trading partner country. This positive transmission to the trading partner's consumption is exacerbated by the sharing of profits in the FI scenario.

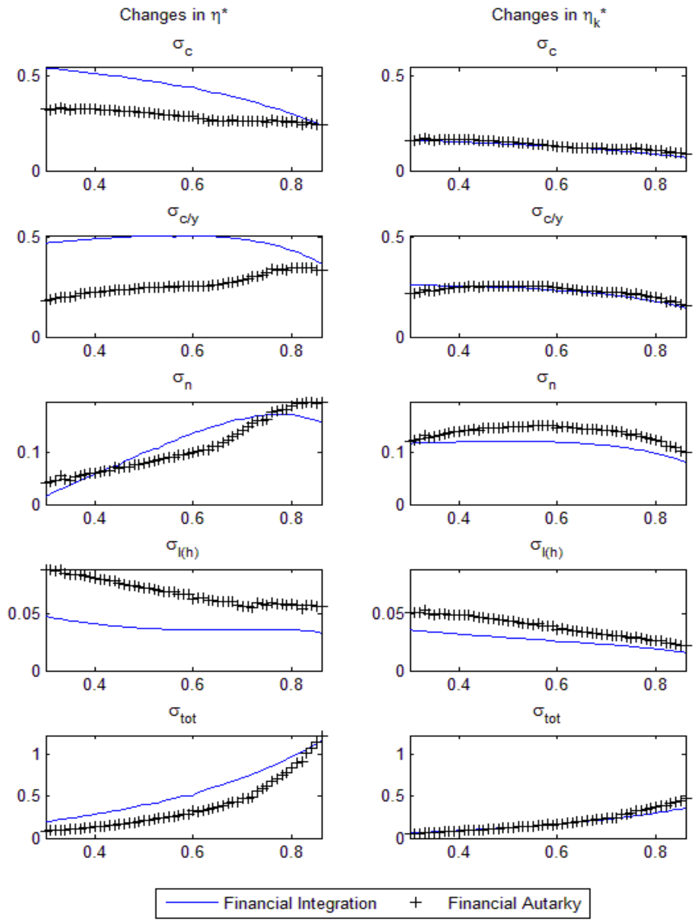

Figure 4: Conditional volatility over trade openness after Foreign shocks

Note: Plots show the standard deviations for Home aggregate variables after η^* and η_K^* shocks. The abscissa represents different levels of $\gamma = \delta$. Therefore, overall openness to trade reduces to the right for both countries. The reference line for the closed economy is not included because these shocks cannot affect an isolated economy.

Consumption-over-GDP for different degrees of trade openness

Figure 5 shows the volatility experienced by the ratio $\frac{C}{Y}$ after a 1% deviation of η and after -1% deviation of η_k for the cases in which only one of the two good markets is open to foreign trade. The figure provides a picture of the transmission of uncertainty from the two real shocks to this ratio through each good market channel. It is clear from Figure 5 that the home bias in capital goods and the home bias in consumption goods drive quite different volatilities of $\frac{C}{Y}$ when a shock occurs. This fact reinforces the relevance of the interaction of both goods markets to explain the aggregate volatilities shown by Figure 3 in the text.[15]

First, notice by comparing subplots (a) and (c) that the non-linearity encountered in the financially integrated economy after a deviation of η has its origins in the capital goods market. Indeed, when the capital goods market is fully closed to foreign trade as in subplot (a) the volatility in the financially integrated economy increases steadily with trade openness (in consumption goods). However, when the consumption goods market is closed to foreign trade (see subplot (c)) the volatility increases for the initial opening up of the capital goods market and decreases afterwards as it becomes more open.

Second, regardless of the source of the shock, the financially integrated economy is more volatile than the financial autarky when only the consumption goods market opens, whereas it is less volatile when only the capital goods market does so. Therefore, the intersection of the two curves in Figure 3 can be explained by the effects caused by the interaction of the two goods markets.

When trade is only possible in capital goods -subplots (c) and (d)-, Foreign households benefit very little from shocks at Home in terms of price reduction. The only benefit they might derive isfrom the fact that more firms are operative in the Home country and this reduces Home prices of final goods, some of which are sold as capital goods to the Foreign country. Consequently, Foreign households spend a little less to create every new firm and, since demand substitution for Home goods is only residual (only in capital goods), more firms are also created in the Foreign country, which reduces the Foreign CPI. Therefore, consumption and output in each country retain most of the effects of the shock within their borders. The latter is true for the financial autarky, where $n^*_{t+1} k(h)^* p(h) = n_{t+1} k(f) p(f)$ to keep a balanced trade balance in capital goods. When countries are financially integrated, Foreign households own part of the Home firms and, therefore, receive part of the Home firms' profits (and share, with Home, part of the reduction of their relative domestic profits), which is an extra channel of risk sharing that cushions part of the volatility of C. Households all over the world allocate larger shares of their savings in Home firms, which are relatively more efficient, thus resulting in a reduction of n^*.

When trade is possible only in consumption goods, the financial autarky must ensure that $C^*_H P_H = C_F P_F$. This scenario allows households to take some advantage of Home cheaper prices via demand substitution. Indeed, they are better able to share the impact of the shocks with Foreign households than in the case of trade in capital goods. However, only households in the financially integrated economy, which are not restricted by a balanced trade, are able to bring demand substitution to its optimal level. This fact increases the effects of any shock and causes foreign prices to rise (relative to P) much more than in the financial autarky, which feedbacks to the demand of Home goods, increases Home real wages and, as a consequence, real consumption.

[15] Recall that shocks on η also reduce the cost of creation via the reduction of final goods prices and, therefore, we cannot "sum" column subplots in Figure 5 to find the results presented in Figure 3. Movements in one goods market affect the other.

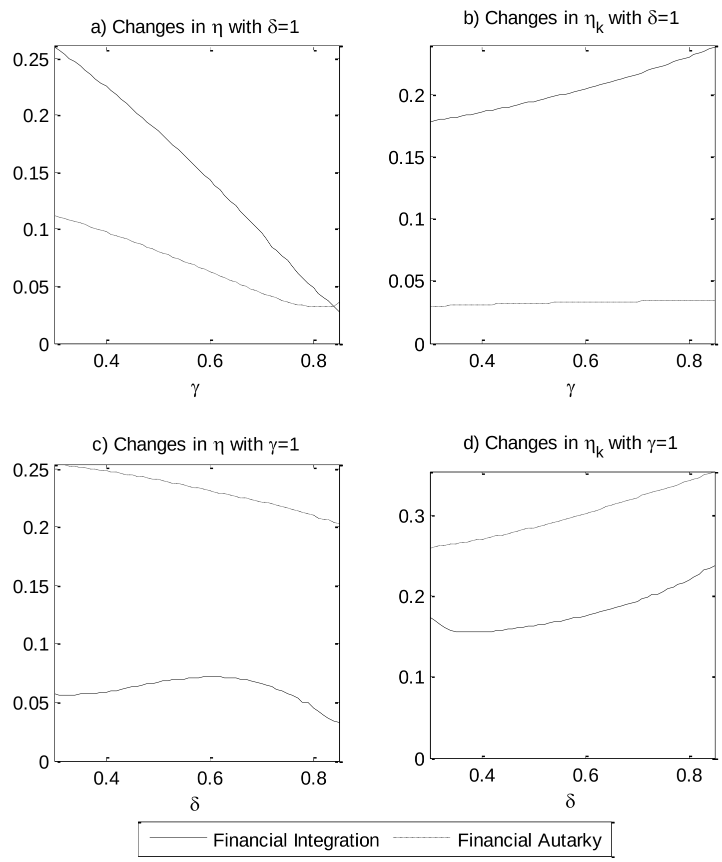

Figure 5: Volatility of C/Y with full home bias in one of the goods market.

Note: The figure shows the volatility of Consumption-over-GDP ratio caused by changes in η and η_K when Home has full home bias either in consumption goods market ($\gamma = 1$) or in capital goods market ($\delta = 1$) and the other market changes its degree of international trade.