

# International Diffusion of Shocks under Different Degrees of Cross-Country Shocks Comovement and Economic Integration

MICHAEL DONADELLI \*

## Abstract

This paper studies the international transmission of shocks under different degrees of cross-country shocks co-movement and economic integration via a two country-two good model with recursive preferences, frictionless markets, and correlated short- and long-run innovations. In contrast to recent studies, I show that the inclusion of cross-country balance sheet linkages and borrowing constraints does not represent a necessary condition to produce a strong international propagation mechanism. The novel risk sharing mechanism embodied in the model produces symmetric and synchronized movements in consumption and stock prices even if there are uncorrelated shocks and segmented goods markets. Nevertheless, model's results give rise to a "quantitative trade-off". On the one side, the presence of correlated long-run growth prospect is needed to produce a relatively low risk-free rate and a relatively high equity risk premium (consistent with asset pricing data), a no-close to unity cross-country consumption growth correlation (consistent with international consumption data), and the Backus-Smith correlation. On the other side, a negative short-run shock is key to produce a large and synchronized drop in real and financial flows (consistently with the properties of the 2008-2009 global demand collapse).

*Keywords:* Long-run innovations, economic integration, international diffusion of shocks

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\*Michael Donadelli is at the Department of Economics and Finance of the LUISS Guido Carli, Rome (michael.donadelli@gmail.com). I am very grateful to Nicola Borri for his support and guidance. I am also grateful to Pierpaolo Benigno, Max Croce, Robert Engle, Pietro Reichlin and Paolo Vitale, as well as to seminar participants at LUISS Guido Carli, Ca' Foscari University of Venice, Brunel University. All errors are the author's responsibility.

# 1 Introduction

During the last 30 years there have been many attempts to match international real and financial data by means of general equilibrium models. Nevertheless, empirical and theoretical international business cycle studies tend to produce conflicting results. For example, while empirical findings suggest that pairs of countries with strong financial linkages (such as US and UK) tend to have highly correlated business cycles (Imbs, 2004, 2006), theoretical models do not produce results that are quantitatively consistent with these findings, a gap known in the literature as “quantity anomaly”.<sup>1</sup> Another key issue emerging from the recent international business cycle literature is related to the number of strong assumptions needed to capture the international propagation mechanism, the nature of the transmission channel and the co-movement across countries. Models’ assumptions are generally related to the structure of the international financial markets, the nature of the shocks hitting the economy, and the persistence of these shocks. Recently developed international business cycle models suggest that market incompleteness is crucial for the international diffusion of shocks and the resolution of the consumption-real exchange rate anomaly (Corsetti et al., 2008; Wada, 2013). In addition, a financial autarky regime seems to account for observed cross-country output, investment and consumption correlations (Heathcote and Perri, 2002). These models do not require additional assumptions. In contrast, models developed in a international complete markets context (i.e. financially integrated markets) seem to be forced to make additional assumptions. On the one side, there are assumptions on the markets’ structure. They rely on the inclusion of financial frictions (i.e. borrowing constraints: Devereux and Yetman, 2010; Devereux and Sutherland, 2011) or labor market frictions (i.e. wage rigidity: Kollmann, 2001; Perri and Quadrini, 2013). On the other side, there are assumptions on the nature of the shocks. A large part of the international business cycle models embody technology shocks (Baxter and Crucini, 1995; Corsetti et al., 2008; Devereux and Yetman, 2010; Kose and Yi, 2006; Wada, 2013, among many others). Some works

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<sup>1</sup>See Backus et al. (1995) and Obstfeld and Rogoff (2001) for a full discussion on the main puzzles in the international business cycle literature.

instead assume credit/financial shocks or both technology and credit/financial shocks (Dedola and Lombardo, 2012; Devereux and Sutherland, 2011; Kollmann, 2001; Perri and Quadrini, 2013). Then, few models make also a distinction on the persistence of the shocks (Baxter and Crucini, 1995; Corsetti et al., 2008; Wada, 2013). Following the observed increase in the degree of economic and financial integration across countries (Figure 2), a large part of the international business cycle literature has focused on the re-resolution of the international macroeconomic data anomalies (e.g. consumption-real exchange rate anomaly, forward premium puzzle). Most recently, following the 2008-2009 unprecedented and synchronized drop in real and financial economic activity across all major industrialized economies (Figure 3), the nature of the international transmission channel, the international diffusion of shocks and the synchronization across cycles have received an enormous amount of attention. Relative, little research, however, has addressed whether different a degree of cross-country shocks co-movement and economic integration is important in terms of improving model's ability in matching international consumption, currency and asset pricing data as well as in reproducing a strong and realistic international co-movement of real and financial flows.

In this paper, I employ a two-country model with recursive preferences, frictionless markets and highly persistent cross-country correlated shocks to study the international diffusion of shocks under different degrees of co-movement between cross-country shocks and economic integration, an aspect neglected in Colacito and Croce (2013) who focus on the resolution of the forward premium and consumption-real exchange rate puzzles, two aspects still subject to controversy.<sup>2</sup> Therefore, I abstract from market incompleteness, financial frictions, and credit/financial shocks. The choice of using this model is motivated by several factors. First, because of recursive preferences, it allows to separate the risk aversion parameter from the intertemporal elasticity of substitution, a key feature to match asset pricing data. Second, it is one of the international business cycle models that is able to reproduce the Backus-Smith correlation by assuming international complete rather than international incomplete markets, a feature of the model in line with the real

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<sup>2</sup>See, for example, Lothian and Wu (2011), and Corsetti et al. (2012).

world where there is a wide array of assets that can be internationally traded (equities, bonds with different maturities, bonds denominated in different currencies, plain vanilla and exotic derivatives), especially across industrialized economies (e.g. US vs UK).<sup>3</sup> Compared to an incomplete markets world, which produces limited consumption risk sharing both internationally and domestically (Crucini, 1999; Santos Monteiro, 2008), the presence of complete markets in the model allows for a stronger consumption risk sharing mechanism. Third, it allows to address whether increased trade is associated with stronger business cycle co-movements (Frankel and Rose, 1998; Kose and Yi, 2006). Formally, it does not include any kind of financial (e.g borrowing constraints) or labor market frictions (e.g. nominal and real wage rigidity) and allows for a strong international propagation mechanism via a unique transmission channel, that is, the trade channel. In practice, the model accommodates the well-known results that the magnitude of the transmission of international shocks increases as bilateral trade increases.<sup>4</sup> In addition, it accommodates recent results showing that the role of cross-country financial linkages during the subprime crisis is marginal. Fourth, it allows to analyze the impact of both highly persistent and not highly persistent cross-country shocks, a key aspect in presence of fully integrated financial markets (Baxter and Crucini, 1995). Last, it embodies home bias in the goods markets, as aspect neglected in the recent international business cycle literature (Bacchetta and van Wincoop, 2013) which allows to study the impact of the economic integration on the international transmission of shocks.

This paper has three main goals. First, I run a sensitivity analysis on the degree of co-movement between home and foreign short- and long-run shocks. The impulse response functions suggest that a shock in the home country affects the consumption growth, stochastic discount factor and stock market return in the foreign country even if there are lowly (negative and positive) correlated or uncorrelated cross-country short- and long-run shocks. Because of recursive preferences and long-run shocks, we just observe

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<sup>3</sup>For a detailed discussion on the robustness of the results obtained in a one-traded bond world, see Benigno and Kucuk-Tuger (2010).

<sup>4</sup>Empirical evidence supporting the idea can be found in Frankel and Rose (1998), Clark and van Wincoop (2001), Calderon et al. (2001), Baxter and Kouparitsas (2004), Santacreu (2011), and Liao and Santacreu (2012).

differences in the sign of the responses. If a positive (negative) short-run news for the supply of the home good takes place, consumption and stock prices will increase (decrease) in both countries. In contrast, upon the realization of long-run shock, consumption and stock prices move in the opposite direction across countries. The latter depends critically on the fact that a long-run shock has a large effect on the lifetime utility value, that is, it produces a decline in future marginal utility and forces agents to reduce the share of home consumption. On the one side, results suggest that the presence of highly-correlated long-run growth prospects is not key to re-produce a strong propagation mechanism. On the other side, they suggest that such presence is crucial to be closer to asset pricing and international consumption data. In particular, I show that under the baseline calibration (Table 1) the model jointly generates a relatively low risk-free rate and a relatively equity risk premium (consistent with asset pricing data, see Table 3), and a relatively low cross-country consumption growth rates (consistent with empirical evidence reported in the international business cycle literature, see Table 3). Therefore, in contrast to existing standard international real business cycle models with complete markets, the model with long-run risk does not induce strong positive cross-country consumption correlations. As an exercise, I re-calibrate and re-estimate the model using estimated values for the correlations between home and foreign short- and long-run innovations. In a linear state space model context and using the Kalman filter as recursive algorithm I obtain a cross-country short-run shocks correlation equal to 0.75 and a cross-country long-run shocks correlation equal to 0.68. While the international propagation mechanism as well as the asset pricing data seem to be unaffected by the different calibration, the simulated real exchange rate volatility and the cross-country consumption growth rates correlation largely change (Table 4).

Second, in the spirit of Bacchetta and van Wincoop (2013), I study the international diffusion of shocks under different degrees of economic integration. In line with recent works aimed at capturing international recessions (Perri and Quadrini, 2013), this part of the analysis focuses on negative shocks. In practice, I study the effects of a negative short- and long-run news realization for the supply of the home good on the foreign

equity and goods markets under different degrees of economic integration. My main findings are as follows: (i) shock are internationally transmitted even if there are highly segmented goods markets; (ii) in presence of full economic integration shocks are perfectly transmitted, that is, the order of magnitude of the impulse response functions is equal across countries; (iii) the impact of a good or bad news to the supply of the home good on the home and foreign consumption and asset prices is synchronized even if there are highly segmented goods markets. In other words, the model is able to produce cross-country co-movements in real and financial variables, consistently with the property of the 2008-2009 global demand collapse.

Third, I investigate whether or not any key moments of some financial and real variables change significantly when I vary the cross-country short- and long-run shock correlation and the consumption home bias parameter. I focus on a subset of statistics that are particular sensitive to these parameters and have received an enormous attention in the international business cycle and asset pricing literature (e.g. risk-free rate, equity risk premium, cross-country consumption growth rates correlation, real exchange rate volatility). I observe that the cross-country consumption growth correlation and the real exchange rate volatility are heavily sensitive to changes in the degree of co-movement between cross-country short- and long-run innovations. The result holds across both models, with and without long-run risk. In particular, in a model with long-run innovations, a lower cross-country long-run shocks correlation produces a negative cross-country consumption growth correlation (inconsistent with international consumption data), and, in a model with no long-run risk, a lower cross-country long-run shocks correlation tend to generate a positive and relatively low cross-country consumption growth correlation (consistent with existing empirical evidence on international consumption data but inconsistent with more recent empirical evidence). Not surprisingly, I also observe that an increasing degree of economic integration produces simultaneously an increase in the co-movement between cross-country consumption growth rates and a decrease in the real exchange rate (i.e. the economy converges to a one-good world and diversification benefits from trading financial assets decrease generating a lower pressure on currency). I conclude by arguing that a

baseline calibration, where long-run growth prospects are highly correlated and countries are highly segmented, is a necessary condition to match international consumption and asset pricing data.

The paper is organized as follows. The next section reviews the literature. Section 3 describes the model and the novel risk-sharing mechanism. Section 4 describes the baseline calibration of the model and studies the international transmission of shocks under different degrees of cross-country shocks co-movement and economic integration. Section 5 describes the quantitative benefits of the trade channel. Section 6 concludes.

## 2 Related literature

This paper is aimed at providing a contribution to the following lines of research: long-run risk, international business cycles and global integration. The paper is most closely related to Colacito and Croce (2010, 2013), Devereux and Yetman (2010), and Bacchetta and van Wincoop (2013). As in Colacito and Croce (2010, 2013), my environment has recursive Epstein and Zin (1989) preferences, long-run risk and frictionless financial markets. As in Devereux and Yetman (2010), I focus on the international transmission of shocks. As in Bacchetta and van Wincoop (2013), my model accounts for different degrees of economic integration.

It is largely accepted that standard international business cycle models have problems in matching international data. In particular, these models tend to generate a close to unity cross-country consumption growth rates correlation, predict negative correlation between investment and employment, and produce low real exchange volatility; whereas data suggest a lower cross-country consumption correlation (or at least in line with cross-country output correlation), a positive correlation between investment and employment, and a higher real exchange rate volatility. It is also largely known that standard models do not solve two important asset pricing puzzles, that is, the equity premium puzzle (Mehra and Prescott, 1985; Mehra, 2003), the risk-free rate puzzle (Weil, 1989), and do not account for the forward premium (Fama, 1984) and Backus and Smith (1993) anomalies.

Recent research has successfully solved some of these puzzles. Early studies (e.g. Baxter and Crucini, 1995; Kollman, 1996) suggest that introducing financial frictions into the model might help to resolve some of the above puzzles. Heathcote and Perri (2002) compare the predictions of a two country-two good model in a financial autarky regime with those generated by a model where economies have a single bond or complete asset markets. They first observe that results under financial autarky and results in presence of complete markets are very different. They also find that values generated by the financial autarky model are closer to the data than those generated by other models. Their result holds over different calibrations. Similarly, under additional assumptions, Benigno and Thoenissen (2008) and Corsetti et al. (2008), in a “two country-one trade bond” environment, are able to produce a relatively low correlations between relative consumption and the real exchange rate. However, Benigno and Kucuk (2010) show that these models fail in reproducing international consumption data once a second trade asset is introduced. Kollmann (2012) argues that the one-traded bond assumption is too strong. Other works show that the inclusion of nominal rigidities allows to produce very volatile real exchange rates and a realistic pattern of the cross-country consumption growth rates correlation (Chari et al., 2002).

Following the international impact of the 9/11 terrorist attacks and the US subprime crisis on the real and financial variables of all the major industrialized economies, the nature of the international transmission channels as well as the diffusion of shocks across countries have attracted an enormous attention in the international business cycle literature. Recent studies argue that standard international business cycle models have also problems in reproducing a strong propagation mechanism (Heathcote and Perri, 2002; Dedola and Lombardo, 2012). This lack in the international transmission of shocks tend to rise also in presence of a high degree of financial integration and is often solved by introducing cross-country correlated shocks in the model. Dedola and Lombardo (2012) employ a two-country model with financial frictions, and show that strong international business cycles co-movements might take place even if there is no correlation between cross-country shocks. In particular, they show that financial shocks generate a stronger



international co-movement of macroeconomic variables than technology shocks. Devereux and Yetman (2010) develop a two-country model with heterogeneous agents (i.e. borrowers and lenders) and leveraged constrained investors. Their model suggests that in absence of leverage constraints on investment, financial integration *per se* has no implications for international macro co-movements. It turns out that financial frictions plays a crucial role in the international propagation mechanism. Bacchetta and van Wincoop (2013) argues that the presence of a one-to-one transmission of shocks in a financially constrained economy relies on the assumption that goods and financial markets are perfectly integrated. Recent studies show that the inclusion of credit shocks rather than technology shocks in an economy characterized by perfectly integrated goods and financial markets is able to generate a one-to-one transmission of shocks (Devereux and Sutherland, 2011; Kollman et al., 2011; Perri and Quadrini, 2013). van Wincoop (2013) develops a model with credit shocks and observes that financial home bias allows for a partial transmission at best. Nevertheless, it has been observed that there is a weak relation between financial linkages that countries have with the United States and the decline in their GDP/consumption growth and asset prices during 2008-2009 (Rose and Spiegel, 2010; Kamin and Pounder, 2012). In contrast, bilateral trade seems to increase the transmission of shocks between countries (Frankel and Rose, 1998; Clark and van Wincoop, 2001; Kose and Yi, 2006, among others). Given that international goods markets still display some degrees of segmentation, Bacchetta and van Wincoop (2013) develop a two country-two period New Keynesian model with consumption home-bias, where the home-bias parameter reflects the degree of goods market integration. They show that a minimum level of economic integration is a sufficient condition to have a business cycle panic. In particular, they are able to match the steep decline in output, consumption and investment during the second half of 2008 and beginning of 2009 in the United States was of similar magnitude of that observed in the rest of the world (Figure 3). Perri and Quadrini (2013) develop a two-country with both credit and technology shocks, and show that a credit tightening produces an endogenous and synchronized drop in economic activity and asset prices, that is, the model is able to reproduce international recessions.

Differently from these studies, I employ a two-country model with recursive preferences, frictionless markets, long-run risk and endowment rather than credit shocks, developed by Colacito and Croce (2013), to study the international diffusion of shocks across countries. I consider two main departures from Colacito and Croce (2010, 2013)'s benchmark model. First, I abstract from the resolution of the forward premium and Backus-Smith puzzles, two aspects largely discussed in the literature and still subject to controversy, and I focus on the international diffusion of short- and long-run innovations. Second, I examine the international propagation mechanism in a scenario characterized by uncorrelated (or negatively correlated) cross-country shocks and different levels of economic integration. My approach is different from previous works in that it does not include any kind of financial frictions and accounts for a unique transmission channel (i.e. the trade channel).

### 3 The Economy

#### Consumption aggregate.

The economy is composed by two countries, home ( $H$ ) and foreign ( $F$ ), and two goods  $X$  and  $Y$ . The home (foreign) country is endowed with good  $X$  ( $Y$ ). Agents' preferences are defined over a consumption aggregate of good  $X$  and good  $Y$ . Formally,

$$C_{H,t} = (x_{H,t})^\alpha (y_{H,t})^{1-\alpha} \quad \text{and} \quad C_{F,t} = (x_{F,t})^{1-\alpha} (y_{F,t})^\alpha \quad (1)$$

where  $C_{H,t}$  and  $C_{F,t}$  are the consumption aggregates in the home and foreign country, respectively,  $x_{H,t}$  and  $y_{H,t}$  denote the consumption of good  $X$  and good  $Y$  in the home country at time  $t$ ,  $x_{F,t}$  and  $y_{F,t}$  denote the consumption of good  $X$  and good  $Y$  in the foreign country at time  $t$ , and  $\alpha \in (0, 1)$  represents the home bias parameter. As introduced by Bacchetta and van Wincoop (2013) in a two country-two period model,  $\alpha > 0.5$  implies that there is preference home bias towards domestic good. Specifically,  $\alpha$  captures the degree of goods market integration. A value of  $\alpha$  close to 1 represents a scenario with highly segmented markets. Clearly,  $\alpha = 1$  implies goods market autarky. If  $\alpha$  is close to

0.5, then markets are perfectly integrated. As suggested by Bacchetta and van Wincoop (2013),  $\alpha = 0.5$  might be associated with perfect economic integration across the home and foreign countries and implies market completeness even if there is no international trade of assets (i.e. the real exchange rate is equal to ratio of the marginal utility of consumption across the countries). As pointed out by Colacito and Croce (2010), if  $\alpha = 0.5$  the economy collapses to a one good world where the risk cannot be diversified and the international trading of financial assets becomes worthless.<sup>5</sup> I measure US goods market home bias in the US using the import of goods-total private consumption of goods ratio for three different trading partners, World, European Union and United Kingdom. I obtain a home bias parameter equal to 0.5, 0.89 and 0.98, respectively.<sup>6</sup> Similarly, Bodenstein (2008) observes that the average ratio of US imports from Canada, Europe, and Japan to US GDP between 1960-2002 is 5% (consistent with  $\alpha > 0.90$ ).

## Preferences.

Agents' preferences in the home and foreign country are recursive. Formally,

$$U_{i,t} = [(1 - \delta)(C_{i,t})^{(1-1/\psi)} + \delta E_t[(U_{i,t+1}^{(1-\gamma)})^{\frac{1-1/\psi}{1-\gamma}}]^{\frac{1}{1-1/\psi}}] \quad (2)$$

where  $i \in (H, F)$ ,  $\gamma$  is the coefficient of relative risk aversion (CRRA), and  $\psi$  denotes the intertemporal elasticity of substitution (IES). In contrast to a standard CRRA specification, preferences in Eq. (2) suggest that agents can be risk averse in future consumption (i.e. future utility), that is, agents have preference for early resolution of uncertainty. Risk aversion to movements in future utility takes place if condition  $\gamma - \frac{1}{\psi} > 0$  holds (i.e. if the CRRA is bigger than the inverse of the IES). The following ordinally equivalent transformation of (2),  $V_t = \frac{U_t^{1-1/\psi}}{1-1/\psi}$ , highlights such recursive preferences' feature. Eq. (2)

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<sup>5</sup>This particular scenario results from the Cobb-Douglas specification and is formally discussed in Cole and Obstfeld (1991)

<sup>6</sup>Total imports of goods and total private consumption of goods series are from the NIPA tables of the Bureau of Economic Analysis and run from 1999 to 2012. The ratio is averaged across the period 1999-2012. Note that the consumption home bias parameter obtained by using the United Kingdom as trading partner is consistent with the US-UK word calibration of Colacito and Croce (2013).

can be written as follows<sup>7</sup>

$$V_t \approx (1 - \delta) \frac{C_t^{1-1/\psi}}{1 - 1/\psi} + \delta E_t[V_{t+1}] - \frac{\delta}{2} \frac{\theta}{E_t[V_{t+1}]} Var_t[V_{t+1}] \quad (3)$$

where  $\theta = \frac{\gamma-1/\psi}{1-1/\psi}$ . Agents have preferences for early resolution of uncertainty if  $\gamma > 1/\psi$ , that is, when  $\theta$  is positive. Under this condition uncertainty about continuation utility,  $Var_t[V_{t+1}]$ , reduces welfare and force agents to trade off future expected utility,  $E_t[V_{t+1}]$ , for future utility risk,  $Var_t[V_{t+1}]$ . This mechanism represents the basis of cross-country movements in allocations and asset prices (Colacito and Croce, 2013). Notice that this preference specification allows to separate the risk aversion parameter from the intertemporal elasticity of substitution, a key feature for the model to be able to match asset pricing data. As shown in Epstein and Zin (1989), the stochastic discount factor in this setting is

$$M_{t+1}^i = \delta \left( \frac{C_{i,t+1}}{C_{i,t}} \right)^{-(1/\psi)} \left( \frac{U_{i,t+1}^{1-\gamma}}{E_t[U_{i,t+1}^{1-\gamma}]} \right)^{\frac{\frac{1}{\psi}-\gamma}{1-\gamma}} \quad (4)$$

where  $i = H, F$ .

## Endowments.

I model endowment dynamics as in Colacito and Croce (2010, 2013). First, endowments are co-integrated processes. Second, variation in the log of the endowment can be explained by an exogenous variable. Formally,

$$\Delta \log X_t = \mu_x + z_{1,t-1} + \tau(\log Y_{t-1} - \log X_{t-1}) + \epsilon_{x,t} \quad (5a)$$

$$\Delta \log Y_t = \mu_y + z_{2,t-1} + \tau(\log X_{t-1} - \log Y_{t-1}) + \epsilon_{y,t} \quad (5b)$$

where  $\tau \in (0, 1)$  is the co-integration parameter, and  $z_{1,t}$  and  $z_{2,t}$  are highly persistent

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<sup>7</sup>A detailed derivation of Eq. (3) can be found in Colacito and Croce (2013).

AR(1) processes

$$z_{1,t} = \rho_1 z_{1,t-1} + \epsilon_{1,t} \quad (6a)$$

$$z_{2,t} = \rho_2 z_{2,t-1} + \epsilon_{2,t}. \quad (6b)$$

I refer to  $\epsilon_{x,t}$  and  $\epsilon_{y,t}$  as short-run shocks and to  $\epsilon_{1,t}$  and  $\epsilon_{2,t}$  as long-run shocks. In contrast to short-run shocks,  $\epsilon_{x,t}$  and  $\epsilon_{y,t}$ ,  $\epsilon_{1,t}$  and  $\epsilon_{2,t}$  have a long-lasting impact on the endowment growth rates. Shocks are distributed as follows

$$\underbrace{\begin{pmatrix} \epsilon_{x,t} \\ \epsilon_{y,t} \\ \epsilon_{1,t} \\ \epsilon_{2,t} \end{pmatrix}}_{\Xi} \sim i.i.d. N \left( \underbrace{\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}}_0, \underbrace{\begin{pmatrix} \sigma_{\epsilon_x}^2 & \sigma_{\epsilon_x, \epsilon_y} & 0 & 0 \\ \sigma_{\epsilon_y, \epsilon_x} & \sigma_{\epsilon_y}^2 & 0 & 0 \\ 0 & 0 & \sigma_{\epsilon_1}^2 & \sigma_{\epsilon_1, \epsilon_2} \\ 0 & 0 & \sigma_{\epsilon_2, \epsilon_1} & \sigma_{\epsilon_2}^2 \end{pmatrix}}_{\Omega} \right) \quad (7)$$

where  $\Xi$  is the shock vector and  $\Omega$  is the variance-covariance matrix of the cross-country short- and long-run shocks. A sensitivity analysis on  $\Omega$  represents one of the most important element of our analysis. As pointed out by Dedola and Lombardo (2012), different values of the elements embodied in  $\Omega$  (i.e.  $\sigma_{\epsilon_x, \epsilon_y}$ ,  $\sigma_{\epsilon_1, \epsilon_2}$ ) might have quantitative implications. In fact a different degree of co-movement between shocks can affects simulated moments (e.g. cross-country consumption correlation, real exchange rate volatility, equity risk premium and riskfree rate) and the strength of the international propagation mechanism. My study is the first to examine the effect of changes in the cross-country correlation of short- and long-run shocks, via a two-country model with recursive preference, long-run risk and frictionless markets, on the international propagation mechanism and resolution of “quantity anomalies”.

### International capital markets.

Given that international financial markets have become increasingly integrated, especially across advanced economies (Figure 2), I focus on a market structure where financial assets are internationally traded. In other words, capital markets are domestically and

internationally complete. Both financial and goods markets have no frictions. Thus, agents are subject to the following budget constraint

$$x_{H,t} + p_t y_{H,t} + \sum_{s_{t+1}} P_{t+1}(s^{t+1}) A_{H,t+1}(s^{t+1}) \leq X_t + A_{H,t} \quad (8a)$$

$$x_{F,t} + p_t y_{F,t} + \sum_{s_{t+1}} P_{t+1}(s^{t+1}) A_{F,t+1}(s^{t+1}) \leq p_t Y_t + A_{F,t} \quad (8b)$$

where  $p_t$  is the price of good Y in terms of good X,  $A_{H,t}(s^t)$  ( $A_{F,t}(s^t)$ ) denotes the claim of country home (foreign) to time  $t$  consumption of good X, and  $P_{t+1}$  is the state-contingent price (i.e. the price of one unit of  $t + 1$  consumption contingent on the realization of  $s^{t+1}$  at time  $t + 1$ ).<sup>8</sup> In equilibrium, the international state-contingent claim market clears

$$A_{H,t} + A_{F,t} = 0 \quad \forall t.$$

### Optimal allocations: Complete markets.

In presence of complete markets, Colacito and Croce (2010, 2013) show that an efficient allocation is the solution a planner's problem choosing a sequence of allocations  $\{x_{H,t}, x_{F,t}, y_{H,t}, y_{F,t}\}_{t=0}^{+\infty}$  to maximize

$$Q = \theta_H U_{H,0} + \theta_F U_{F,0}$$

subject to the following feasibility constraints:

$$x_{H,t} + x_{F,t} = X_t; \quad y_{H,t} + y_{F,t} = Y_t \quad \forall t \geq 0$$

where  $\theta_H$  and  $\theta_F$  are the date 0 non-negative Pareto weights attached to the consumer by the planner. The first order conditions of the social planning problem imply the following Pareto optimal allocation

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<sup>8</sup>Note that under financial autarky there is no trade of assets (i.e.  $A_t = 0, \forall t, \forall s_{t+1}$ )

$$x_t^H = \alpha X_t \left[ 1 + \frac{(1-\alpha)(S_t-1)}{1-\alpha+\alpha S_t} \right], \quad x_t^F = (1-\alpha) X_t \left[ 1 + \frac{\alpha(S_t-1)}{1-\alpha+\alpha S_t} \right] \quad (9a)$$

$$y_t^H = (1-\alpha) Y_t \left[ 1 + \frac{\alpha(S_t-1)}{\alpha+(1-\alpha)S_t} \right], \quad y_t^F = \alpha Y_t \left[ 1 + \frac{(1-\alpha)(S_t-1)}{\alpha+(1-\alpha)S_t} \right] \quad (9b)$$

where

$$S_t = S_{t-1} \frac{M_{H,t}}{M_{F,t}} \left( \frac{C_{H,t}/C_{H,t-1}}{C_{F,t}/C_{F,t-1}} \right).$$

As in Andersen (2005), the first order condition holds for all dates, for all states and for all agents H and F when  $\theta_H, \theta_F > 0$ , and  $S_t$  denotes the ratio of time-varying pseudo-Pareto weights,  $\frac{\theta_H}{\theta_F}$ . We can think of  $S_t$  as the share of world consumption. In addition, it is easily verifiable that for  $S_t = 1$  the optimal allocation under complete markets and the optimal allocation under financial autarky are equal.<sup>9</sup>

## 4 Quantitative analysis

The extensive literature on the international business cycle co-movements has focused mainly on the resolution of the quantitative anomalies (e.g. consumption-real exchange rate anomaly, forward premium puzzle, cross-country consumption growth rate puzzle) under *ad hoc* calibrations. In this section I extend the analysis of the business cycle co-movements into two main directions. First, I analyze how the international propagation mechanism is affected by different degrees of co-movement between home and foreign short- and long-run innovations and economic integration. Second, I investigate whether or not any key moments of some financial and real variables change when I vary the cross-country short- and long-run shocks correlation and the consumption home bias parameter. I focus on a subset of statistics that are particularly sensitive to different levels of cross-country shocks co-movement and economic integration.

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<sup>9</sup>Under financial autarky financial markets are internationally incomplete (Cole and Obstfeld, 1991). Goods market trade takes place and is balanced in every period. It turns out that the absence of an international trading activity does not allow for intertemporal consumption smoothing.

## 4.1 Baseline calibration

Table 1 reports the set of parameter values employed by Colacito and Croce (2010, 2013) in their baseline calibration. The calibration of the long-run risk components is based on the post-1970 era, a period of increasing financial and economic integration across all major industrialized economies (Figure 2). The remaining calibrated parameters match previous works in the long-run risk literature. If there is no long-run risk (i.e.  $\sigma = 0$ ), the baseline calibration is modified by assuming  $\rho_{xy} = 0.35$ .

Table 1: Baseline Calibration.

Parameter	Value	Parameter	Value
$\mu$ Endowment long-run growth rate	2.00%	$\alpha$ Consumption home-bias	0.97
$\sigma$ Long-run shock volatility	1.87%	$\tau$ Co-integration parameter	0.05%
$\sigma_x$ Short-run shock volatility	14% $\sigma$	$\delta$ Subjective discount factor	0.98
$\rho$ Long-run component persistence	0.985	$\gamma$ Relative risk aversion	8
$\rho_{12}$ Long-run shocks correlation	0.90	$\psi$ Intertemporal elasticity of substitution	1.5
$\rho_{xy}$ Short-run shocks correlation	0.05	$\rho_{xy}$ Short-run shocks correlation (no LRR)	0.35

## 4.2 International propagation of shocks under different degrees of co-movement between cross-country shocks

Standard international business cycle models with complete markets tend to have problems in matching international data as well as to reproduce a strong propagation mechanism. On the one side, the risk sharing mechanism embodied in these models produces a close to unity cross-country consumption growth correlation. As observed by Backus et al. (1992), in an open economy framework, consumption is more highly correlated across countries and output is less highly correlated across countries than we see in the data. On the other side, existing models are not able to match the increasing positive international co-movements of the main macroeconomic variables generated by an increasing financial and economic integration. This problem is often resolved by assuming cross-country correlation of the shocks.<sup>10</sup> More recent works point out that the transmission channels in existing models are heavily driven by the trade and financial linkages and by the type shocks. While in models with technology shocks output tends

<sup>10</sup>For example, Backus et al. (1992) assume a cross-country technology shocks correlation of 0.28.



to be lowly or negatively correlated across countries even with perfectly integrated goods and financial markets, recent models including credit or financial shocks seem to produce a one-to-one transmission of shocks. For example, Dedola and Lombardo (2012) show that, in presence of financial frictions and under financial integration, financial shocks might reproduce a strong propagation mechanism even if there is no correlation between home and foreign shocks.

This section shows that the novel risk-sharing mechanism embodied in the model allows for a strong propagation mechanism independently of the level of co-movement between short- and long-run news. To assess the implications of different degrees of co-movement between short- and long-run shocks for the transmission channel and international data, I analyze the impulse response functions depicted in Figures (4)-(13), where I first consider the case of a positive short-run shock to the supply of good  $X$ , and then I turn my attention to a positive long-run shock. Figures (4)-(8) report the impulse response functions generated by a model with no long-run risk and different degrees of co-movement between short-run shocks. Figures (9)-(13) report the impulse response functions generated by a model with long-run risk and different degrees of co-movement between long-run shocks (and fixed cross-country short-run shocks correlation). The results of the short-run world suggest that shocks are internationally transmitted as well as synchronized even with negative correlated (or uncorrelated) cross-country shocks. A positive short-run shocks (i.e. an increase in the supply of good  $X$ ) induces the home country to export part of the extra amount of good  $X$ . It turns out that consumption increases in both countries. Nevertheless, the presence of home bias forces the foreign country to take only a fraction of the good supplied by the home country. Therefore, consumption will increase relatively more in the home country (see the left columns of Figures (4)-(8)). Because of the excess supply of good  $X$ , the home currency depreciates. Therefore, as pointed out in Croce and Colacito (2013), there is a positive correlation between consumption growth differentials and exchange rate (i.e. short-run shocks do not solve the Backus-Smith puzzle). Impulse response functions generated by a model with long-run risk confirm that different cross-country long-run shock correlations do not alter

the strength of the propagation mechanism. In addition, the effects of a long-run shock are still synchronized across countries but display opposite signs. In a scenario where a positive long-run shock materializes, consumption growth and asset prices (i.e. returns) decrease in the home country, and increase in the foreign country (see the right columns of Figures (9)-(13)). Because of the long-lasting nature of the long-run shock, agents face a rise in continuation utility, that is, a decline in future marginal utility. Therefore, it is optimal to reduce the share of consumption allocated to the home country where the marginal utility is low. It turns out that resources flow from the home country to the foreign country producing a long-lasting decrease in home consumption (see Figure (13)). This mechanism is embodied in  $S_t$ . Since consumption and asset prices increase in the foreign country, there is a negative consumption growth differential. Because of the expectation of a persistently larger future supply of the home good, the home currency depreciates. As in Colacito and Croce (2013), I show that a positive long-run shock produces negative co-movements between consumption growth differentials and exchange rate (i.e. Backus-Smith anomaly). I stress that the result holds for different degrees of co-movement between long-run shocks.

On the one side, a short-run shock world seems to produce results in line with the recent literature aimed at examining the international propagation mechanism and, in particular, the international recessions, as well as the effects of the global integration process on international asset prices. I show that shock are internationally transmitted and symmetrically synchronized even if there are uncorrelated cross-country shocks and frictionless financial markets. Moreover, I observe that a positive short-run shock to the home good produces an increase in the stock market index of both countries. It turns out that a trade shock tend to affect international stock market prices, that is, expected returns decrease as global trade increases (de Jong and de Roon, 2005; Donadelli, 2013). On the other side, the results of a model with long-run shocks and different degrees of co-movement between long-run components are able to match asset pricing data. In particular, the model with highly correlated long-run innovations produces a relatively low risk-free rate and a relative high equity risk premium.

### 4.3 The benefits of a model with long-run risk

Table 3 reports the simulated moments (under complete markets) for different degrees of co-movements between home and foreign short- and long-run shocks. In other words, it shows the main moments of the variables of interest generated by the models employed to produce the impulse response functions presented in Figures (4)-(13). The home bias parameter,  $\alpha$ , the CRRA,  $\gamma$ , and the IES,  $\psi$ , are as in Table 1, and equal across all model's specification. Panel A reports the simulated moments produced by a model with no long-run risk for a cross-country short-run shocks correlation that ranges from 0.35 to -0.35. Specification (1) in Panel A represents the baseline calibration in absence of long-run risk. As pointed out by Colacito and Croce (2013), a model with no long-run risk tend to generate inconsistent moments. Specifically, regardless of the level of co-movements between home and foreign short-run shocks, it produces a relatively high consumption growth rates correlation and relatively low real exchange rate volatility, and it does not solve the risk-free rate and equity premium puzzles. Nevertheless, the recursive structure of agents' preferences seem to force the risk-free rate to maintain relative low values. Panel B reports the simulated moments produced by a model with long-run risk. The main moments are reported for different levels of co-movement between home and foreign long-run shocks (specifications (6)-(10) in Table 2). While the cross-country short-run shocks correlation is set to be as in the baseline calibration, the cross-country long-run shocks correlation ranges from 0.9 to -0.9. In line with Colacito and Croce (2013), a model with recursive preferences, highly correlated long-run growth prospects and consumption home bias produce relatively low cross-country consumption growth rates correlation (consistent with empirical findings reported in previous works but inconsistent with more recent empirical evidence), and highly correlated stochastic discount factors (consistent with international asset pricing data). The result is mainly driven by the fact that continuation utilities are highly correlated (i.e.  $Corr(U_{H,t+1}, U_{F,t+1}) \equiv 1$ ), that is, under complete markets marginal utilities are equal across countries. In contrast, if cross-country long-run shocks are lowly (positive/negative) or uncorrelated the model does not match international consumption data, and produce a highly negative correlation

between the home and foreign consumption growth rates. It turns out that the inclusion of correlated long-run growth prospects seem to be crucial to produce a relatively low risk-free rate and a relatively high equity risk premium as well as the Backus-Smith correlation.

#### 4.4 Evidence from a model with estimated cross-country shocks correlation

Differently from Colacito and Croce (2013), and Bansal et al. (2010), who run a set of predictive regressions to capture short- and long-run shocks, I identify short- and long-run innovations by means of state space models. The US and UK total real private consumption proxies for the total endowment in the home and foreign country, respectively. To be consistent with my endowment economy, I exclude government expenditure. In practice, I identify short- and long-run shocks to US and UK endowments by jointly estimating the system of equations (5a) and (5b) and the system of equations (6a) and (6b), where  $z_{1,t}$  and  $z_{2,t}$  are assumed to be unobserved state variables.<sup>11</sup> My empirical results confirm the presence of a weak co-integration relationship between the U.S. and U.K. consumption series, thus, they justify  $\tau = 0.0005$ .<sup>12</sup> Estimating the set of equations over three different time-horizons (1980-2012, 1985-2012 and 1990-2012), I obtain an average cross-country short- and long-run innovation correlation equal to 0.75 and 0.68, respectively. I re-simulate the model employing these estimates. Key moments are reported in Table 4. My main results are as follows. First, I observe that the degree of co-movement between cross-country innovations does not affect the international propagation mechanism and produces small changes in simulated asset pricing data.<sup>13</sup> Second, I show that the presence of a lower degree of co-movements between long-run innovations in the model with long-run risk produces a lower cross-country consumption growth correlation and a higher real exchange rate volatility. Third the presence of a higher degree

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<sup>11</sup>A similar approach can be found in Suzuki (2013).

<sup>12</sup>Estimation results are available upon request.

<sup>13</sup>For space reasons the impulse response functions generated by the re-calibrated model are not reported. Figures are available upon request and similar to Figures (4)-(13).

of co-movements between short-run innovations in the model with no long-run risk produces a higher cross-country consumption growth correlation and a lower real exchange rate volatility.

## **4.5 International propagation of shocks under different degrees of economic integration**

Following the international effects of the subprime crisis, where the United States, industrialized European economies and other non-industrialized countries experienced extraordinarily large and synchronized contractions in both real and financial aggregates during the last quarter of 2008 and the first quarter of 2009 (see Figure 3), the number of studies examining the nature of the international transmission channels and the effects of international shocks has largely increased. Being largely accepted that standard international business cycle models face problems in reproducing a strong propagation mechanism even if there is market completeness, the literature has started to focus on models with different transmission channels and types of shocks. In presence of perfectly integrated goods and financial markets and credit rather than technology shocks, recent works show that a strong propagation mechanism might take place.<sup>14</sup> Nevertheless, international goods and financial markets still present some degrees of segmentation. It turns out that existing models, in presence of weaker trade and financial linkages, might produce a partial transmission. Under the assumption that goods markets are not perfectly integrated, Bacchetta and van Wincoop (2013) show that a drop in output, consumption and investment can be of similar magnitude even if there is a minimum level of economic integration. They prove this by developing a two country-two period model where a synchronized contraction in real and financial aggregates results from a self-fulfilling panic and not from an exogenous shock to fundamentals.

In the spirit of Bacchetta and van Wincoop (2013), I study the effects of different degrees of economic integration on the international co-movements in consumption and share price indexes. To capture international recessions, I mainly focus on negative short-

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<sup>14</sup>See Devereux and Sutherland (2011), and Perri and Quadrini (2013), among others.

run shocks. In contrast to the most recent literature, I show that an exogenous short-run shock to the supply of domestic good,  $X$ , produces a synchronized decline in asset prices and consumption even if there are highly segmented markets and endowment rather than credit or financial shocks. Figures (15)-(18) report impulse responses to a negative short- (left-columns) and long-run (right-columns) shock to the supply of good  $X$ . The model developed in this paper shows that a synchronized decline in asset prices and economic activity takes place even in presence of partial integration and in absence of credit or financial shocks (see Figures (15)-(18)). In particular, a negative short-run news to the supply of the home good - with a consumption home bias parameter of 0.9 and 0.75 - produces a drop in consumption and asset prices of similar magnitude in the two countries (see left columns of Figures (16)-(17)). As in Bacchetta and van Wincoop (2013), my results support the idea that, in order to have a global panic, the level of economic integration does not need to be high. While a model with short-run shock seems to perfectly replicate the 2008-2009 synchronized international economic and financial collapse, a model with long-run shock, because of the expected rise in continuation utility (i.e. decline in future marginal utility) which implies a decline in the share of world consumption and a subsequent rise in foreign consumption, generates movements in home and foreign asset prices and consumption with different signs. Nevertheless, if full economic integration (i.e.  $\alpha = 0.5$ ) takes place, the drop in consumption and asset prices produced by short-and long-run innovations is equal (and synchronized) across countries (Figure 18). In this case, the economy collapses to a one good economy where the long-run benefits of financial integration disappear, that is, under perfect economic integration risks cannot be diversified and the international trade activity of financial assets is worthless. In other words, perfect economic integration implies market completeness even if there is no asset trade.

Table 5 reports the simulated moments (under complete markets) for different degrees of economic integration and three different combinations of  $\gamma$  and  $\psi$ . To get asset and international data implications, main moments are reported for the model with and without long-run risk. Results suggests that a different degree of economic integration

does not affect the equity premium and risk-free rate. It turns out that a model with long-run risk resolves the two puzzles, regardless of the level of economic integration. In addition, in line with Bansal and Yaron (2004) a higher  $\psi$  produces a higher equity risk premium (see Panel C). In contrast, a different degree of economic integration seems to affect the cross-country consumption correlation and the real exchange rate volatility. First, the correlation of consumption growth rates across countries increases with economic integration (i.e.  $\alpha = 0.75$ ) and it becomes equal to one in presence of full economic integration (see also Bodenstein, 2008). Second, the model shows that the real exchange rate volatility decreases as  $\alpha$  decreases and it jumps to zero for  $\alpha = 0.5$ . In contrast to financial autarky, full financial integration allows agents to freely trade international securities, thus, there is high pressure on currency. It turns out that under complete financial markets the real exchange rate volatility is higher than under financial autarky. But the closer is  $\alpha$  to 0.5 the more the model reflects a one good economy where financial markets are internationally complete even with no trade, that is, no pressure on currency (i.e.  $\sigma(ex) = 0$ ). These results are similar across models (with and without long-run risk), and clear in Figure 1 which plots simulated moments (i.e. consumption correlation, RER volatility, risk-free rate, equity risk premium) against different levels of economic integration. I stress that the inclusion of the long-run risk components allows for the resolution of the equity premium and the risk-free rate puzzles and, in presence of highly-correlated long-run prospects (i.e.  $\rho_{1,2} = 0.9$ ) and low economic integration (i.e.  $\alpha = 0.97, 0.90$ ), helps to produce a relatively low cross-country consumption growth correlation and a relatively high real exchange rate volatility (consistent with previous empirical findings).<sup>15</sup>

#### 4.6 Matching a *tsunami*: The benefits of the trade channel

Figure 3 shows that the steep decline in consumption, industrial production, trade and stock indexes during the last quarter of 2008 and the first quarter of 2009 in the United States and in the rest of the rest of the world was of similar magnitude. While many

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<sup>15</sup>See Dedola et al. (2008), and Colacito and Croce (2013), among others.

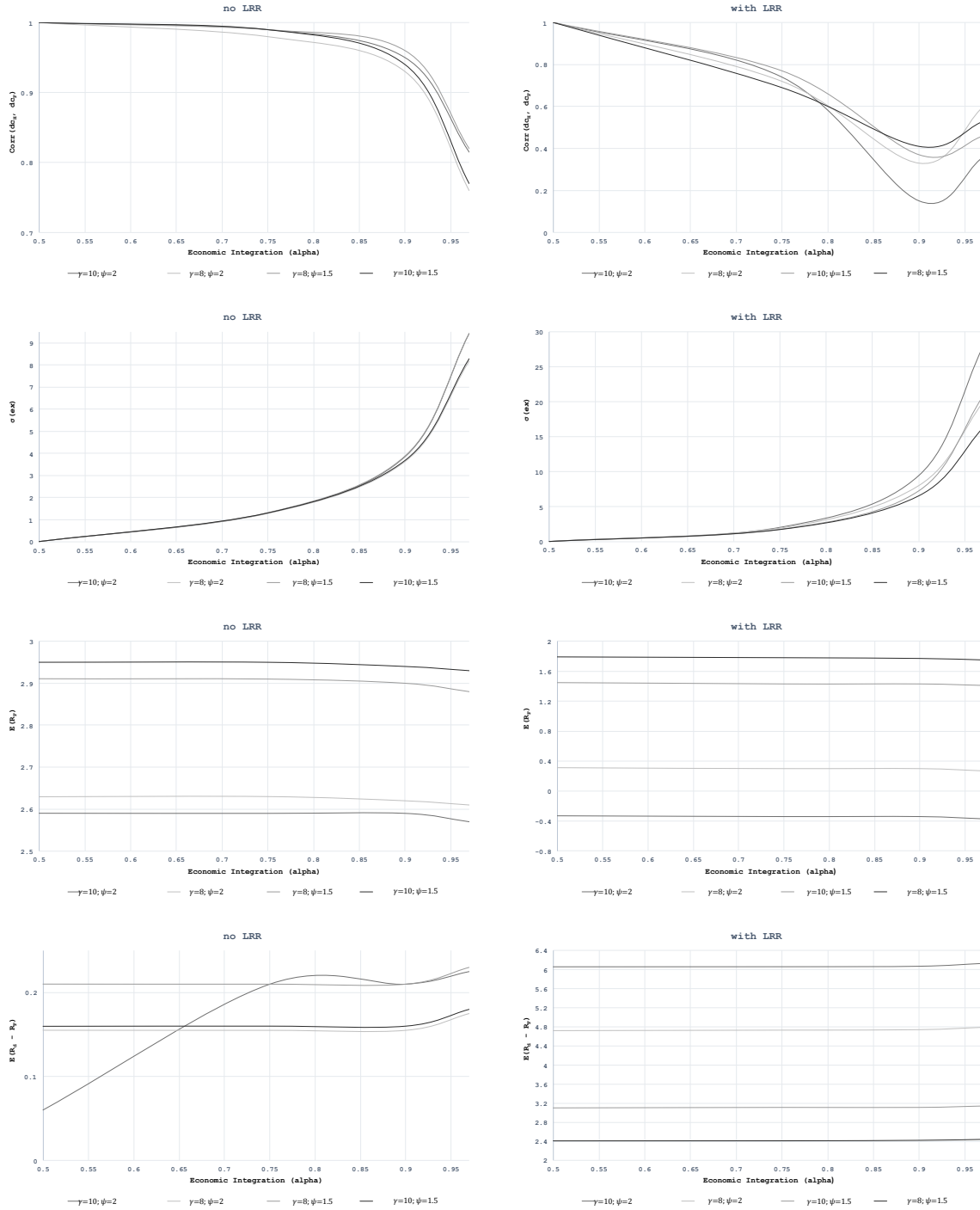


Figure 1: **Simulated moments (complete markets): Consumption correlation, RER volatility, risk-free rate, equity risk premium vs economic integration.** *Notes:* This figure plots the cross-country consumption growth rates correlation,  $Corr(dc_h, dc_f)$ , and real exchange rate volatility,  $\sigma(ex)$ , risk-free rate,  $E(R_f)$ , and equity risk premium,  $E(R_d - R_f)$ , (on the vertical axes) against the consumption home bias parameter (on the horizontal axes) for different values of  $\gamma$  and  $\psi$ . The left column reports moments simulated via a model with no long-run risk (“no LRR”). The right column reports moments simulated via a model with long-run risk (“with LRR”). All sub-figures are based on simulated moments reported in Table 5. Key moments are obtained from 5,000 simulated periods (100 simulations, 50 periods).



studies refer to this event as a *domino effect* (e.g. Blanchard, 2009; Cheung and Guichard, 2009; Bacchetta and van Wincoop, 2013), that is, the result of a combination of different phenomena, I would prefer to refer to it as a *tsunami* (i.e. a unique, extraordinary large and synchronized contraction in both real and financial measures). It is also widely agreed that the simultaneous downturn seen in all regions during the last quarter of 2008 and the first quarter of 2009 is unprecedented in post-war history.

Open economy models usually produce limited co-movement between business cycles. Such results might be caused by a partial transmission (through trade and financial linkages) of exogenous country specific shocks. Recent works examining the international propagation of shocks in a financially integrated world point out that standard business cycle models tend to have problems in reproducing a strong propagation mechanism (e.g. Devereux and Yetman, 2010; Heathcote and Perri, 2002; Dedola and Lombardo, 2012). In other words, standard models with exogenous shocks and limited integration might generate only partial transmission. On the one side, such problems can be solve by assuming cross-country correlated shocks. Nevertheless, the inclusion of cross-country correlated shocks tend to generate extremely high cross-country consumption correlations. On the other side, recent models show that the inclusion of different types of shocks (e.g. credit or financial shocks) can generate stronger international business cycle co-movements even if there are uncorrelated shocks and partially integrated markets.

The risk-sharing mechanism of this model offers a unified framework to address the international transmission of shocks in presence of segmented markets, different degree of co-movement between cross-country exogenous endowment shocks and frictionless financial markets. Model's results provide clear evidence about the importance of the trade channel. In contrast to Devereux and Yetman (2010) who argue that it is unlikely that trade linkages alone could account for the synchronized drop in economic growth rates seen in all regions during the 2008-2009 crisis, I show that trade channel, which represents the unique transmission channel of the model, is capable to reproduce the observed *tsunami*. My result lies in a conventional wisdom where the order of magnitude of transmission of shocks between two countries increases as bilateral trade increases (Frankel and

Rose, 1998; Kose and Yi, 2006). In particular, as a result of a negative short-run news to the supply of the home good, the home and foreign countries experience a large and endogenously synchronized drop in asset prices and consumption. If economic integration increases, then the difference between a drop in domestic and foreign consumption and asset prices decreases (Figures (15)-(18)). In other words, a bad news to the supply of the home good generates international co-movement in asset prices and consumption, consistently with the property of the 2008-2009 global demand collapse.

## 5 Concluding remarks

This paper develops a two-country model with Epstein and Zin (1989) recursive preferences, long-run risk a la Bansal and Yaron (2004), cross-country correlated short- and long-run shocks a la Colacito and Croce (2007, 2013), and frictionless markets to study the diffusion of shocks across countries in presence of different degrees of cross-country shocks co-movement and economic integration, an aspect neglected in Colacito and Croce (2013) who focus only on the resolution of the forward premium puzzle (Fama, 1984) and Backus and Smith (1993) anomaly. This model is different from existing models in that it does not include frictions and credit or financial shocks, embodies segmentation in international goods markets and provides asset pricing implications. The contribution of this paper is to take very seriously the role of cross-country shocks correlation and economic integration in the international diffusion of shocks. First, I show that the model produces strong international co-movements in response to country-specific endowment shocks even if there are uncorrelated cross-country short- and long-run shocks. Second, the novel risk-sharing mechanism of the model allows for a strong international propagation mechanism even if there are highly segmented goods markets. Moreover, I find that as the level of economic integration increases the difference between a drop in home and foreign consumption and asset prices - generated by a negative short-run shock to the supply of  $X$  - decreases (i.e. cross-country co-movements in real and financial variables increase as bilateral trade increases). These findings are new in the international

real business cycle literature and suggest that the model with short-run shocks is able to generate international co-movement in real and financial variables (consistently with the property of the subprime crisis) even if there are no cross-country balance sheet linkages and borrowing constraints.

I conclude by arguing that there is a trade-off between the use of a model with short-run news only and a model with long-run news. On the one side, the impulse response functions generated by a short-run bad news to the supply of the home good seem to be able to capture international co-movements in real and financial flows during recession periods. On the other side, simulated moments produced by a model with long-run news seem to be consistent with asset pricing data. In addition, in presence of highly correlated long-run growth prospects and segmented goods markets, the model produces a relatively low cross-country consumption correlation and a relatively high real exchange rate volatility (consistent with existing empirical findings but inconsistent with more recent empirical evidence). However, key moments studied in this paper are sensitive to relatively large changes in the degree of cross-country shocks co-movement and economic integration.

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## A Data sources

ASSET MARKET (*Source*: Fama and French Data Library + FED St. Louis):

- Real annualized return of a risk-free rate asset: The return of 1-month Treasury bill (1970-2012);
- Real return on S& P 500: Annual average Standard and Poor's Composite Stock Price Index - Annual Average Consumer Price Index (1970-2000);
- Equity risk premium: Difference between the risk-free return and the equity return (1970-2012).

REAL MARKET (*Source*: OECD + FED):

- U.K. real private consumption growth rate (1970-2012);
- U.S. real private consumption growth rate (1970-2012);
- Real exchange rate: Nominal exchange rate plus the GDP deflator growth rate differentials (1970-2012);

Table 2: **Key statistics:**  $E(R_f)$  = Real annualized return of a risk-free rate asset;  $E(R_d - R_f)$  = Real return on S& P 500;  $Corr(dc_H, dc_F)$  = cross-country consumption growth rate correlation;  $\sigma(ex)$  = real exchange rate volatility.

Sample:	$E(R_f)$	$E(R_d - R_f)$	$Corr(dc_H, dc_F)$	$\sigma(ex)$
1970-2012	0.95	1.99	0.70	8.91
1980-2012	1.47	4.10	0.79	8.96
1985-2012	1.10	4.99	0.81	7.60
1990-2012	0.64	4.14	0.87	7.02

## B Stylized facts

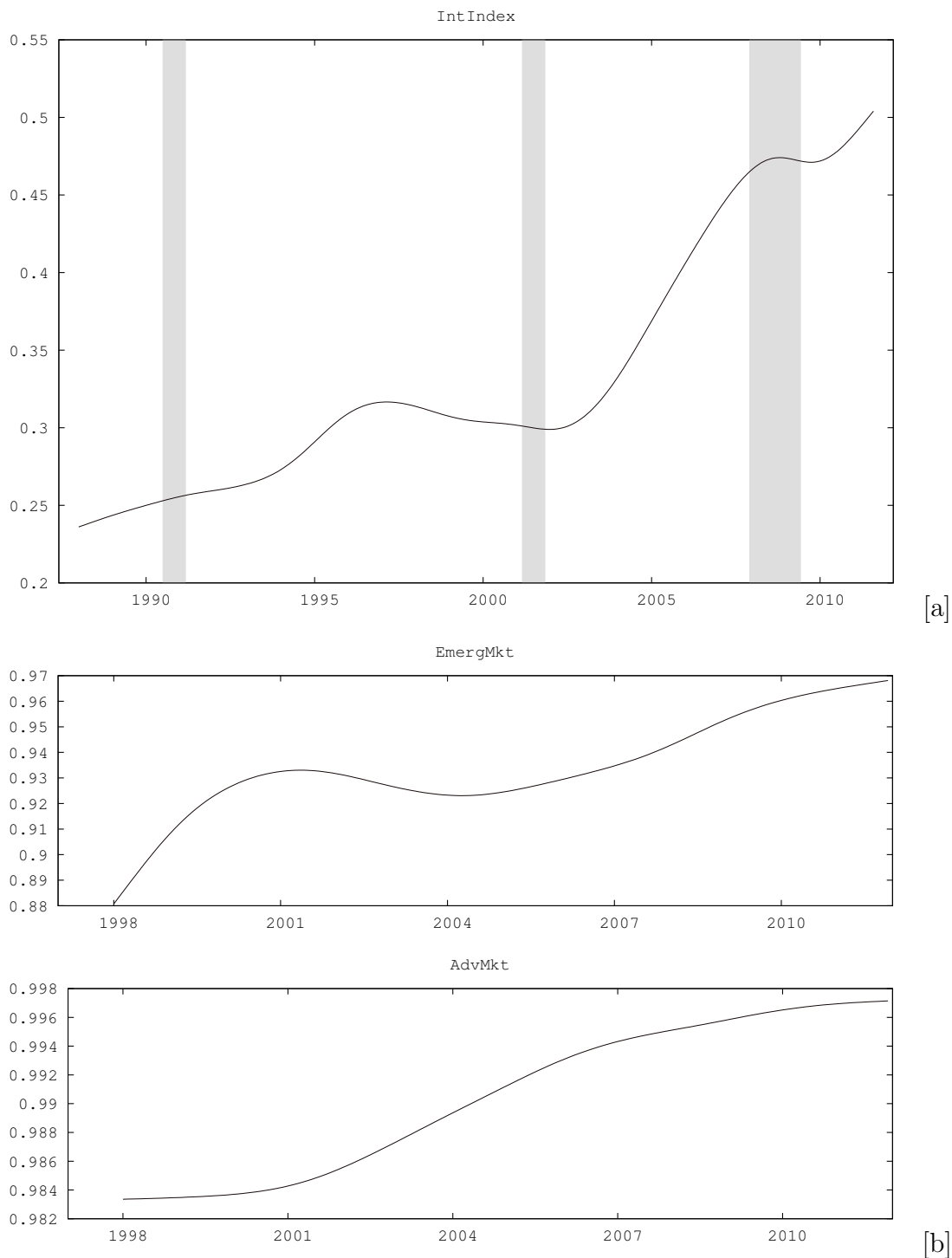


Figure 2: **Economic and financial integration.** *Notes:* The economic integration process (panel [a]) is represented by the world trade-to-GDP ratio. The financial integration across developed and emerging markets (panel [b]) is given by the dynamics of the  $R_2$  of a multi-*(artificial)* factor regression. *Source:* Based on Donadelli (2013).



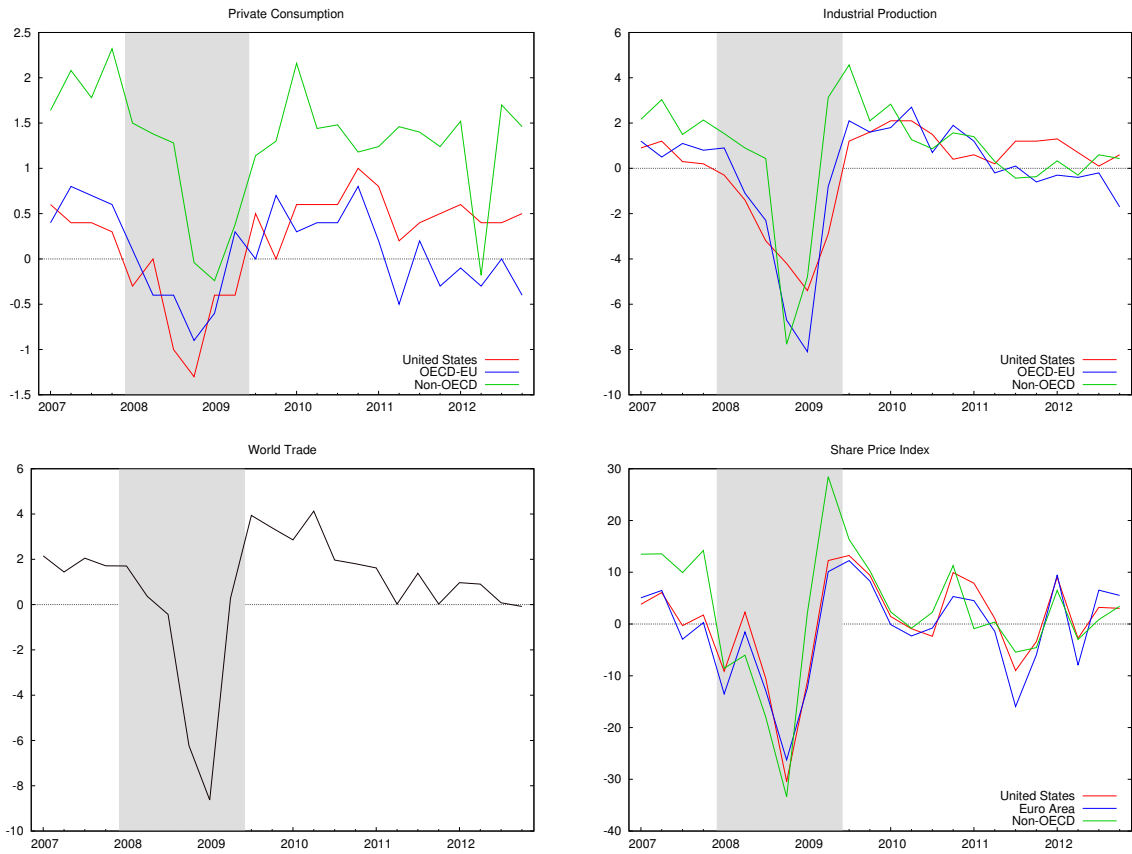


Figure 3: **The 2008-2009 recession: Real and financial aggregates.** World trade in goods and services is measured in billions of U.S. dollars. Non-OECD values are obtained as averages of non-OECD members observations. Non-OECD includes Brazil, India, Indonesia, Russia and South Africa. All series are seasonally adjusted. Data are quarterly and run from 2007 (1Q) to 2012 (4Q). *Source:* OECD

## C Quantitative results

Table 3: **Results with complete markets and different degree of co-movement between home and foreign short- and long- run shocks.** *Notes:* For all specifications, I impose  $\gamma = 8$ ,  $\psi = 1.5$  and  $\alpha = 0.97$  (as in the baseline calibration). Panel A reports the main moments for five specifications featuring different short-run shocks correlation. For specifications (1)-(5), I impose  $\sigma = 0$ . Panel B reports the main moments for five specifications featuring different long-run shocks correlation. For specifications (6)-(10), I impose  $\rho_{\epsilon_x, \epsilon_y} = 0.05$  (as in the baseline calibration). Data sample: 1980-2012. All entries for the model are obtained from 5,000 simulated periods (100 simulations, 50 periods).

Panel A: no LRR						
	(1)	(2)	(3)	(4)	(5)	Data
$Corr(\epsilon_x, \epsilon_y)$	$\rho_{\epsilon_x, \epsilon_y} = 0.35$	$\rho_{\epsilon_x, \epsilon_y} = 0.1$	$\rho_{\epsilon_x, \epsilon_y} = 0$	$\rho_{\epsilon_x, \epsilon_y} = -0.1$	$\rho_{\epsilon_x, \epsilon_y} = -0.35$	
$E(R_f^H)$	2.93	2.94	2.95	2.96	2.98	1.47
$E(R_d^H - R_f^H)$	0.18	0.15	0.15	0.14	0.13	4.10
$Corr(dc_H, dc_F)$	0.77	0.65	0.58	0.51	0.31	0.79
$\sigma(ex)$	8.29	9.86	10.50	11.99	12.41	8.96

Panel B: with LRR						
	(6)	(7)	(8)	(9)	(10)	
$Corr(\epsilon_1, \epsilon_2)$	$\rho_{\epsilon_1, \epsilon_2} = 0.9$	$\rho_{\epsilon_1, \epsilon_2} = 0.1$	$\rho_{\epsilon_1, \epsilon_2} = 0$	$\rho_{\epsilon_1, \epsilon_2} = -0.1$	$\rho_{\epsilon_1, \epsilon_2} = -0.9$	
$E(R_f^H)$	1.75	2.40	2.36	2.40	2.97	1.47
$E(R_d^H - R_f^H)$	2.44	1.45	1.41	1.34	0.53	4.10
$Corr(dc_H, dc_F)$	0.53	-0.80	-0.83	-0.84	-0.92	0.79
$\sigma(ex)$	16.34	100.81	113.58	124.71	263.36	8.96

Table 4: **Results with complete markets and estimated cross-country short- and long- run shocks.** *Notes:* For both models, I impose  $\gamma = 8$ ,  $\psi = 1.5$  and  $\alpha = 0.97$  (as in the baseline calibration). Short and long-run shocks are estimated as described in the text. Average cross-country short- and long-run shocks correlations are 0.75 and 0.68, respectively. Data sample: 1980-2012. All entries for the model are obtained from 5,000 simulated periods (100 simulations, 50 periods).

Model	with LRR	no LRR	Data
$E(R_f^H)$	1.84	2.90	1.47
$E(R_d^H - R_f^H)$	2.29	0.23	4.10
$Corr(dc_H, dc_F)$	-0.07	0.92	0.79
$\sigma(ex)$	28.20	5.09	8.96

Table 5: **Key Moments: Results with complete markets and different degrees of economic integration** *Notes:* Panel A reports simulated moments for different degrees of economic integration under the baseline calibration. Panels B, C and D report simulated moments for different degrees of economic integration and combinations of  $\gamma$  and  $\psi$ . The equity excess return,  $E(R_d^H - R_f^H)$ , is computed from the aggregate dividend index. Note that in Colacito and Croce (2013) the equity excess return is computed as follows:  $r_{d,t}^{ex} = \lambda r_{c,t}^{ex} + \epsilon_{i,t}$ , where  $\lambda = 3$ ,  $r_{c,t}^{ex}$  is the excess return on the consumption claim, and  $\epsilon_{i,t}$  is a dividend-specific shocks. Data sample: 1980-2012. All entries for the model are obtained from 5,000 simulated periods (100 simulations, 50 periods).

Model	with LRR				no LRR				
Home Bias	$\alpha = 0.97$	$\alpha = 0.9$	$\alpha = 0.75$	$\alpha = 0.5$	$\alpha = 0.97$	$\alpha = 0.9$	$\alpha = 0.75$	$\alpha = 0.5$	Data
Panel A $\gamma = 8, \psi = 1.5$	(1a)	(2a)	(3a)	(4a)	(5a)	(6a)	(7a)	(8a)	
$E(R_f^H)$	1.75	1.77	1.78	1.79	2.93	2.94	2.95	2.95	1.47
$E(R_d^H - R_f^H)$	2.44	2.42	2.41	2.41	0.18	0.16	0.16	0.16	4.10
$Corr(dc_H, dc_F)$	0.53	0.41	0.69	1.00	0.77	0.94	0.99	1.00	0.79
$\sigma(ex)$	16.34	6.56	1.75	0.00	8.29	3.69	1.31	0.00	8.96
Panel B $\gamma = 10, \psi = 1.5$	(1b)	(2b)	(3b)	(4b)	(5b)	(6b)	(7b)	(8b)	
$E(R_f^H)$	1.41	1.43	1.43	1.45	2.88	2.90	2.91	2.91	
$E(R_d^H - R_f^H)$	3.14	3.11	3.11	3.10	0.23	0.21	0.21	0.21	
$Corr(dc_H, dc_F)$	0.46	0.37	0.77	1.00	0.82	0.96	0.99	1.00	
$\sigma(ex)$	20.89	7.27	1.78	0.00	9.44	3.89	1.32	0.00	
Panel C $\gamma = 8, \psi = 2$	(1c)	(2c)	(3c)	(4c)	(5c)	(6c)	(7c)	(8c)	
$E(R_f^H)$	0.27	0.30	0.30	0.31	2.61	2.62	2.63	2.63	
$E(R_d^H - R_f^H)$	4.79	4.74	4.73	4.72	0.18	0.16	0.16	0.16	
$Corr(dc_H, dc_F)$	0.60	0.33	0.72	1.00	0.76	0.93	0.98	1.00	
$\sigma(ex)$	20.00	8.02	1.95	0.00	8.18	3.64	1.29	0.00	
Panel D $\gamma = 10, \psi = 2$	(1d)	(2d)	(3d)	(4d)	(5d)	(6d)	(7d)	(8d)	
$E(R_f^H)$	-0.37	-0.34	-0.34	-0.33	2.57	2.59	2.59	2.59	
$E(R_d^H - R_f^H)$	6.13	6.07	6.06	6.06	0.23	0.21	0.21	0.06	
$Corr(dc_H, dc_F)$	0.36	0.15	0.74	1.00	0.82	0.96	0.99	1.00	
$\sigma(ex)$	27.99	9.45	2.06	0.00	9.43	3.86	1.30	0.00	

## Evidence from a model with no long-run risk

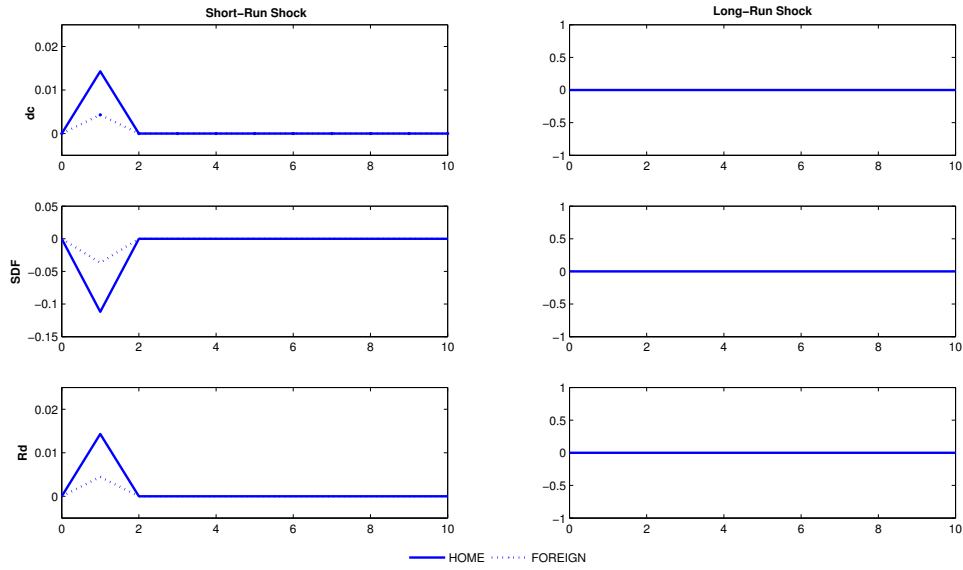


Figure 4: **Impulse response functions with no long-run risk.** This figure presents the impulse response functions of consumption growth ( $dc$ ), stochastic discount factor (SDF) and stock market return ( $Rd$ ) for both the home (solid line) and foreign country (dashed line). All parameters are calibrated to the values reported in table 1 for specification (1) in table 3 (i.e.  $Corr(\epsilon_x, \epsilon_y) = 0.35$ ). A positive  $\sigma_x$  shock in the short-run, and a positive  $\sigma$  shock in the long-run materialize only in the home country, and only at time 1.

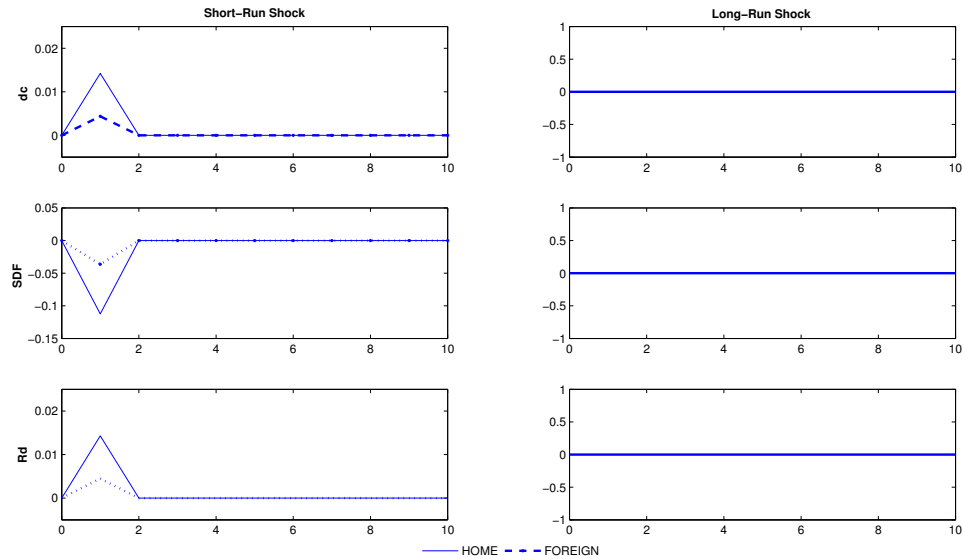


Figure 5: **Impulse response functions with no long-run risk.** This figure presents the impulse response functions of consumption growth ( $dc$ ), stochastic discount factor (SDF) and stock market return ( $Rd$ ) for both the home (solid line) and foreign country (dashed line). All parameters are calibrated to the values reported in table 1 for specification (2) in table 3 (i.e.  $Corr(\epsilon_x, \epsilon_y) = 0.1$ ). A positive  $\sigma_x$  shock in the short-run, and a positive  $\sigma$  shock in the long-run materialize only in the home country, and only at time 1.

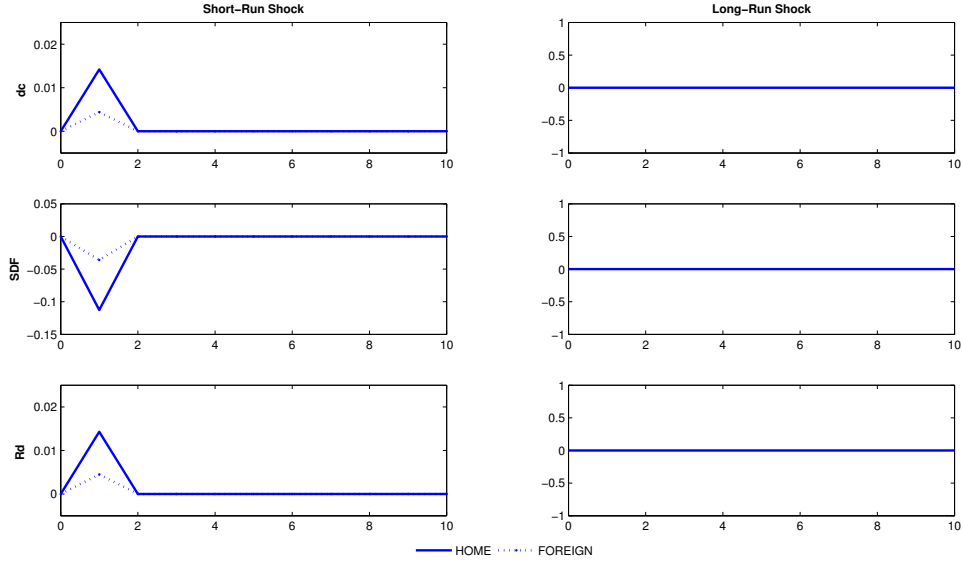


Figure 6: **Impulse response functions with no long-run risk.** This figure presents the impulse response functions of consumption growth ( $dc$ ), stochastic discount factor (SDF) and stock market return (Rd) for both the home (solid line) and foreign country (dashed line). All parameters are calibrated to the values reported in table 1 for specification (3) in table 3 (i.e.  $Corr(\epsilon_x, \epsilon_y) = 0$ ). A positive  $\sigma_x$  shock in the short-run, and a positive  $\sigma$  shock in the long-run materialize only in the home country, and only at time 1.

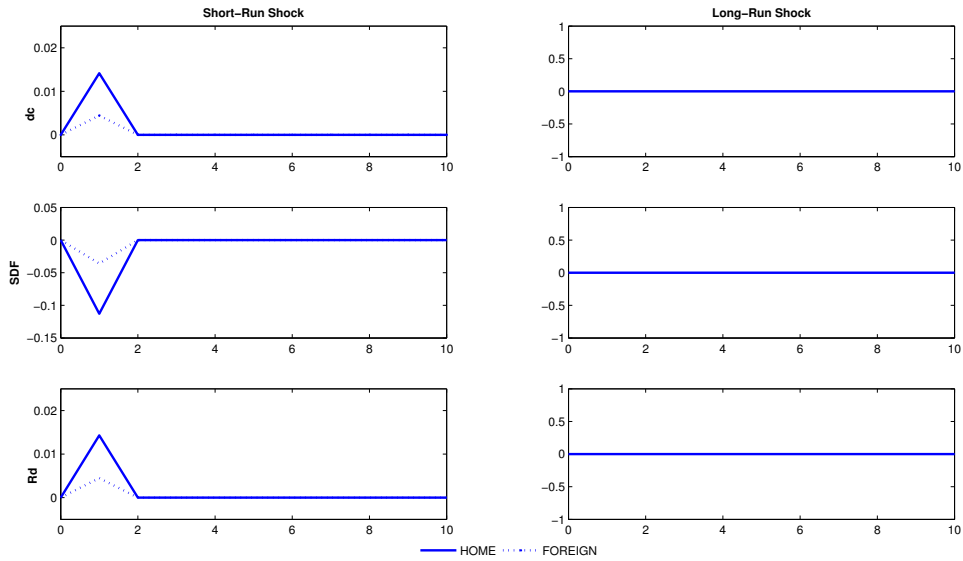


Figure 7: **Impulse response functions with no long-run risk.** This figure presents the impulse response functions of consumption growth ( $dc$ ), stochastic discount factor (SDF) and stock market return (Rd) for both the home (solid line) and foreign country (dashed line). All parameters are calibrated to the values reported in table 1 for specification (4) in table 3 (i.e.  $Corr(\epsilon_x, \epsilon_y) = -0.1$ ). A positive  $\sigma_x$  shock in the short-run, and a positive  $\sigma$  shock in the long-run materialize only in the home country, and only at time 1.

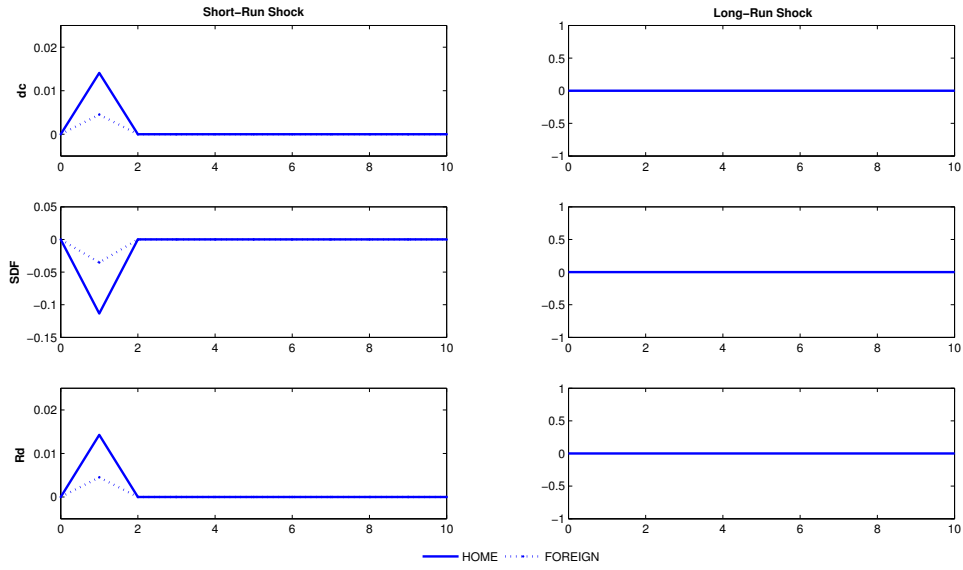


Figure 8: **Impulse response functions with no long-run risk.** This figure presents the impulse response functions of consumption growth ( $dc$ ), stochastic discount factor (SDF) and stock market return (Rd) for both the home (solid line) and foreign country (dashed line). All parameters are calibrated to the values reported in table 1 for specification (5) in table 3 (i.e.  $Corr(\epsilon_x, \epsilon_y) = -0.35$ ). A positive  $\sigma_x$  shock in the short-run, and a positive  $\sigma$  shock in the long-run materialize only in the home country, and only at time 1

## Evidence from a model with long-run risk

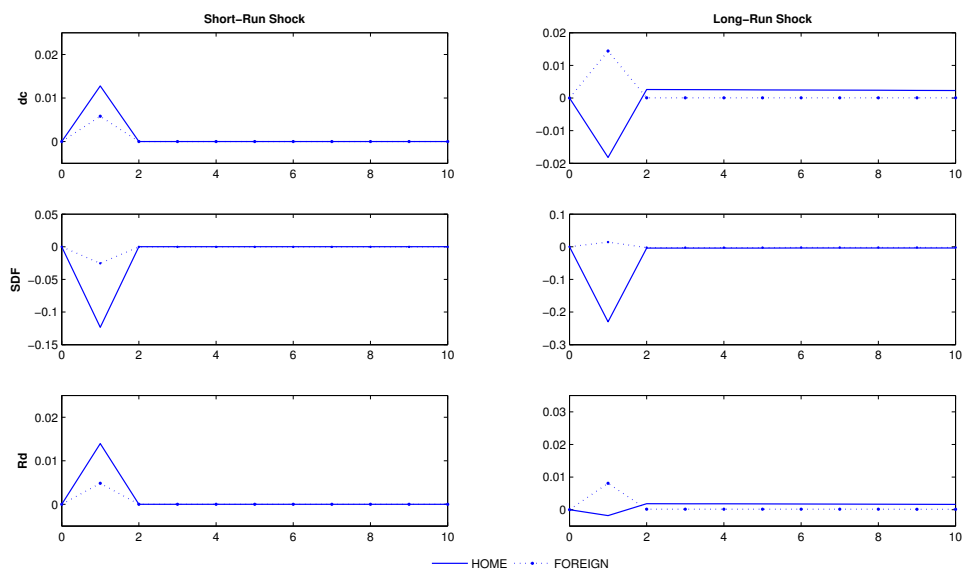


Figure 9: **Impulse response functions with long-run risk.** This figure presents the impulse response functions of consumption growth (dc), stochastic discount factor (SDF) and stock market return (Rd) for both the home (solid line) and foreign country (dashed line). All parameters are calibrated to the values reported in table 1 for specification (6) in table 3 (i.e.  $Corr(\epsilon_1, \epsilon_2) = 0.9$ ). A positive  $\sigma_x$  shock in the short-run, and a positive  $\sigma$  shock in the long-run materialize only in the home country, and only at time 1

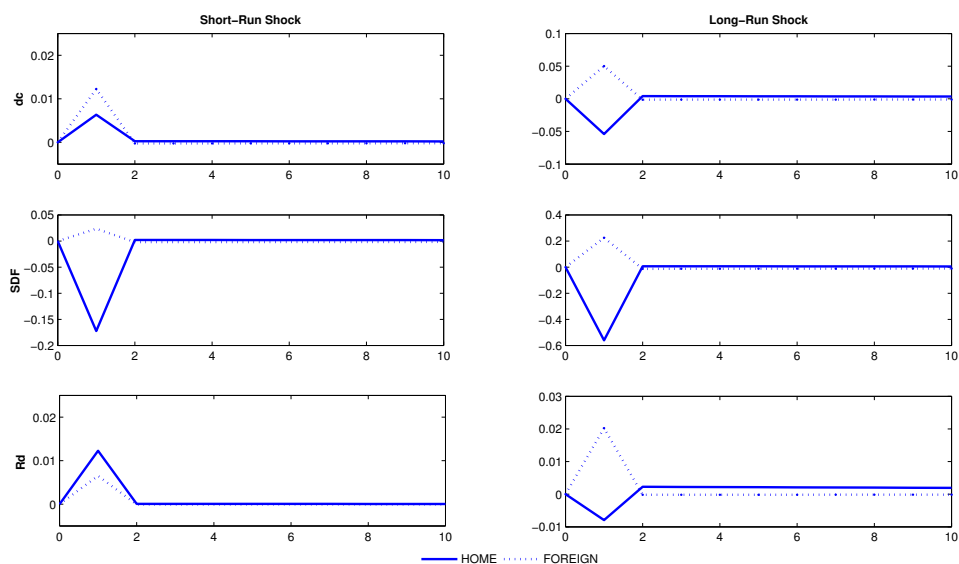


Figure 10: **Impulse response functions with long-run risk.** This figure presents the impulse response functions of consumption growth (dc), stochastic discount factor (SDF) and stock market return (Rd) for both the home (solid line) and foreign country (dashed line). All parameters are calibrated to the values reported in table 1 for specification (7) in table 3 (i.e.  $Corr(\epsilon_1, \epsilon_2) = 0.1$ ). A positive  $\sigma_x$  shock in the short-run, and a positive  $\sigma$  shock in the long-run materialize only in the home country, and only at time 1

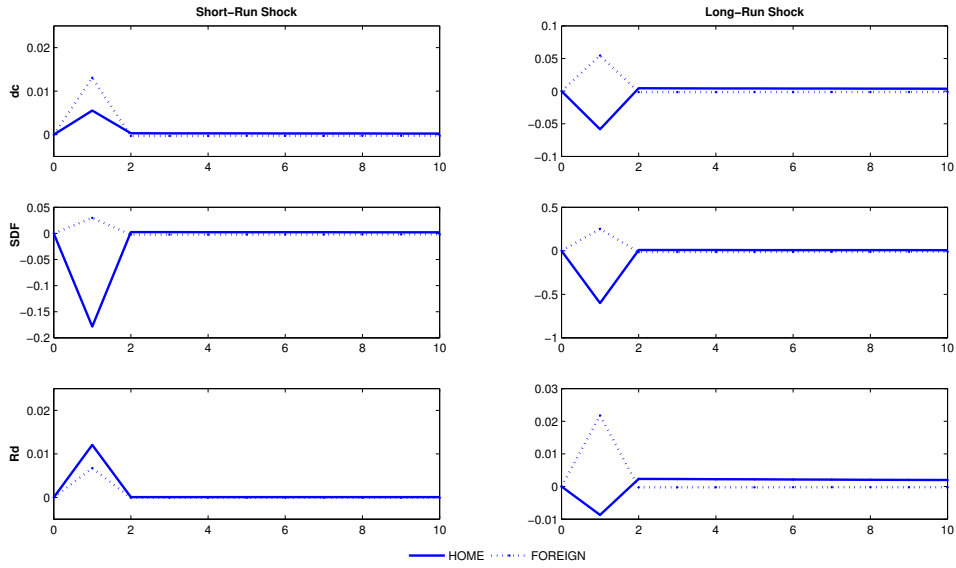


Figure 11: **Impulse response functions with long-run risk.** This figure presents the impulse response functions of consumption growth ( $dc$ ), stochastic discount factor (SDF) and stock market return (Rd) for both the home (solid line) and foreign country (dashed line). All parameters are calibrated to the values reported in table 1 for specification (8) in table 3 (i.e.  $Corr(\epsilon_1, \epsilon_2) = 0$ ). A positive  $\sigma_x$  shock in the short-run, and a positive  $\sigma$  shock in the long-run materialize only in the home country, and only at time 1

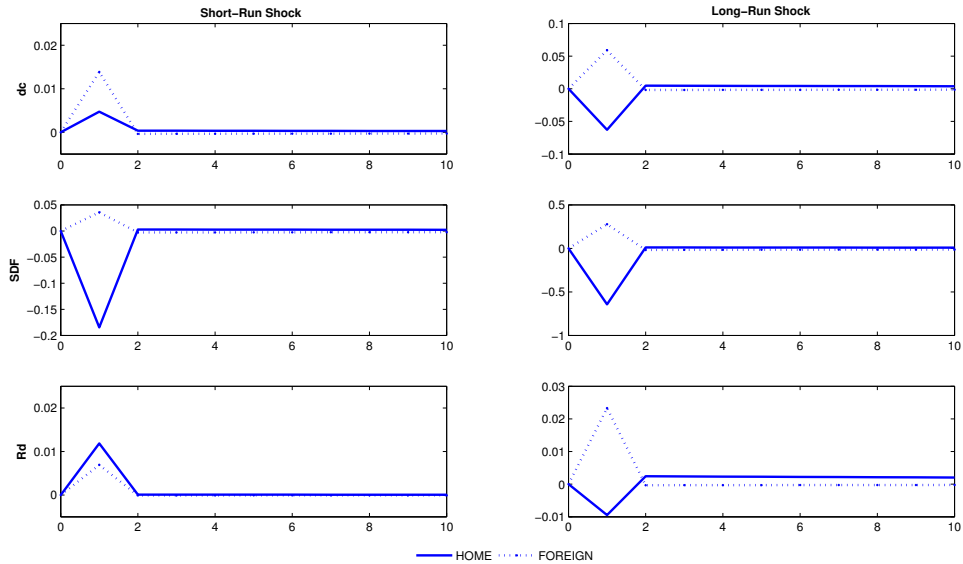


Figure 12: **Impulse response functions with long-run risk.** This figure presents the impulse response functions of consumption growth ( $dc$ ), stochastic discount factor (SDF) and stock market return (Rd) for both the home (solid line) and foreign country (dashed line). All parameters are calibrated to the values reported in table 1 for specification (9) in table 3 (i.e.  $Corr(\epsilon_1, \epsilon_2) = -0.1$ ). A positive  $\sigma_x$  shock in the short-run, and a positive  $\sigma$  shock in the long-run materialize only in the home country, and only at time 1



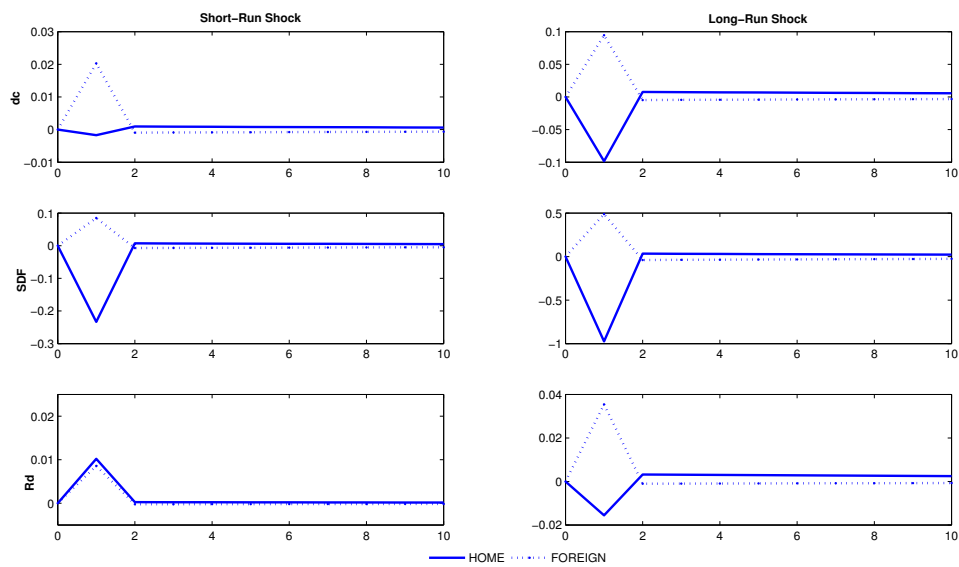


Figure 13: **Impulse response functions with long-run risk.** This figure presents the impulse response functions of consumption growth ( $dc$ ), stochastic discount factor (SDF) and stock market return ( $Rd$ ) for both the home (solid line) and foreign country (dashed line). All parameters are calibrated to the values reported in table 1 for specification (10) in table 3 (i.e.  $Corr(\epsilon_1, \epsilon_2) = -0.9$ ). A positive  $\sigma_x$  shock in the short-run, and a positive  $\sigma$  shock in the long-run materialize only in the home country, and only at time 1

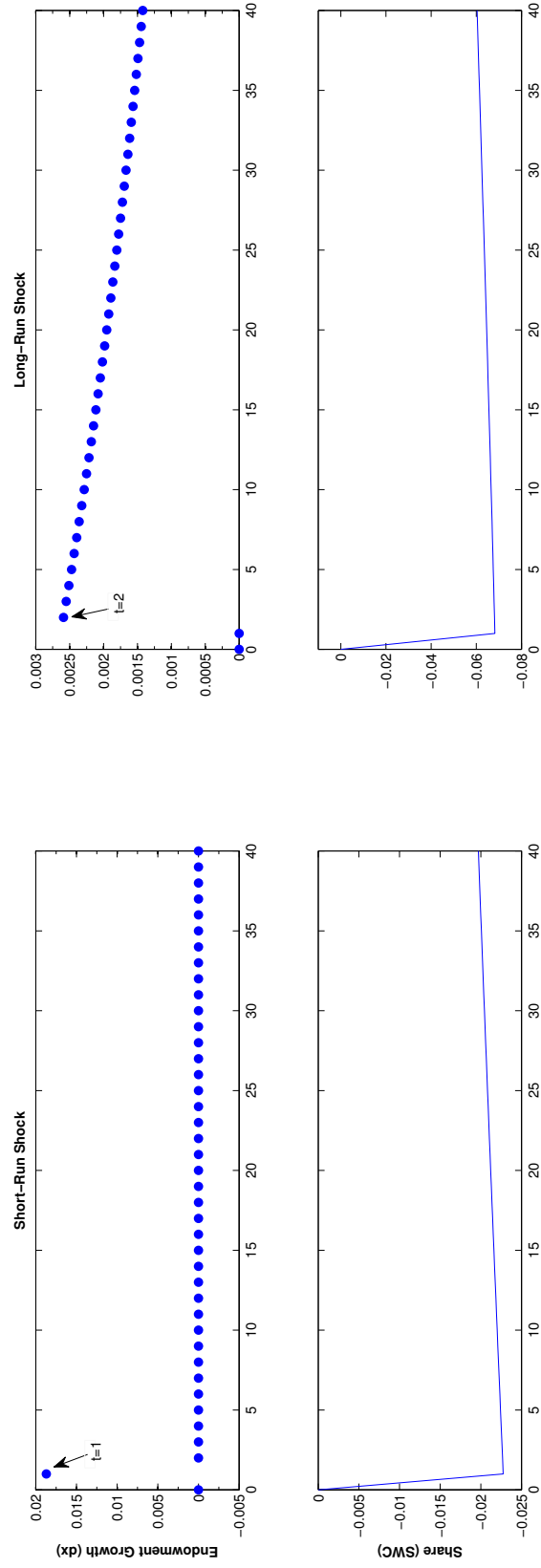
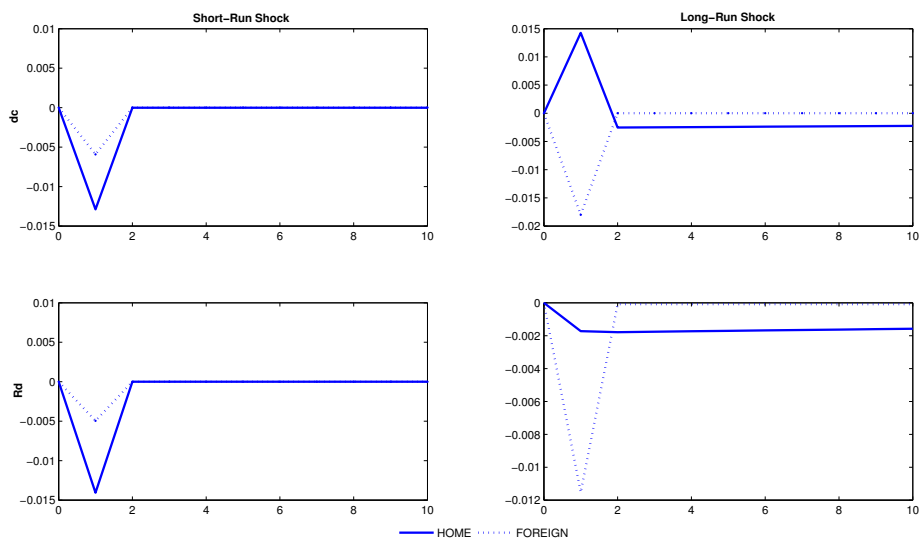
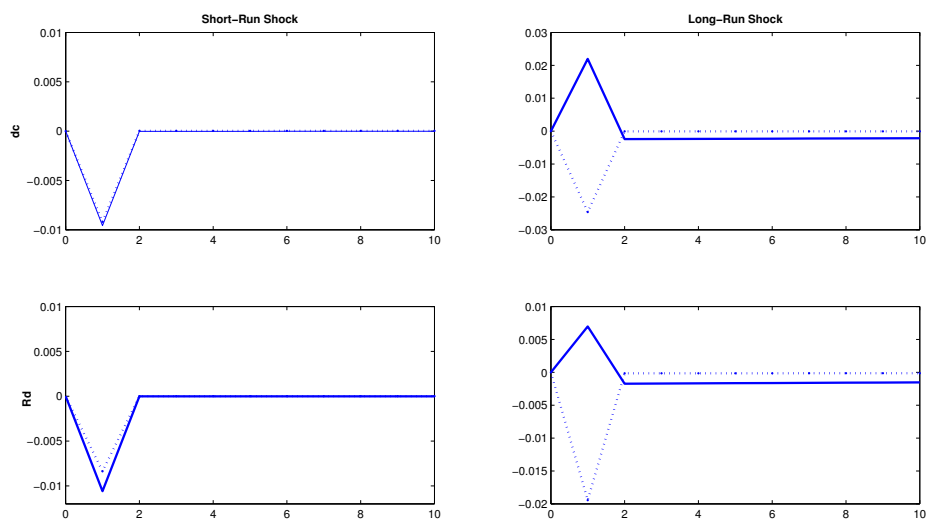


Figure 14: **The trade channel and the share of world consumption.** This figure presents the impulse response function of the world consumption share of the home country (bottom panel) and the dynamics of the shocks (top panel). Endowment shocks materialize only in the home country, and only at time 1. Domestic and foreign shocks are cross-country correlated in the model (see Eq. (8)). All parameters are calibrated to the values reported in table 1.

## Evidence from a model with different degrees of consumption home-bias



**Figure 15: Impulse response functions with long-run risk and partial economic integration.** This figure presents the impulse response functions of consumption growth ( $dc$ ) and stock market return ( $Rd$ ) for both the home (solid line) and foreign country (dashed line). All parameters are calibrated to the values reported in table 1. The consumption home bias parameter,  $\alpha$ , is 0.97 and denotes partial economic integration. Impulse response functions are based on specification (1a) in table 5. A negative  $\sigma_x$  shock in the short-run, and a negative  $\sigma$  shock in the long-run materialize only in the home country, and only at time 1.



**Figure 16: Impulse response functions with long-run risk and partial economic integration.** This figure presents the impulse response functions of consumption growth ( $dc$ ) and stock market return ( $Rd$ ) for both the home (solid line) and foreign country (dashed line). All parameters are calibrated to the values reported in table 1. The consumption home bias parameter,  $\alpha$ , is 0.90 and denotes partial economic integration. Impulse response functions are based on specification (2a) in table 5. A negative  $\sigma_x$  shock in the short-run, and a negative  $\sigma$  shock in the long-run materialize only in the home country, and only at time 1.

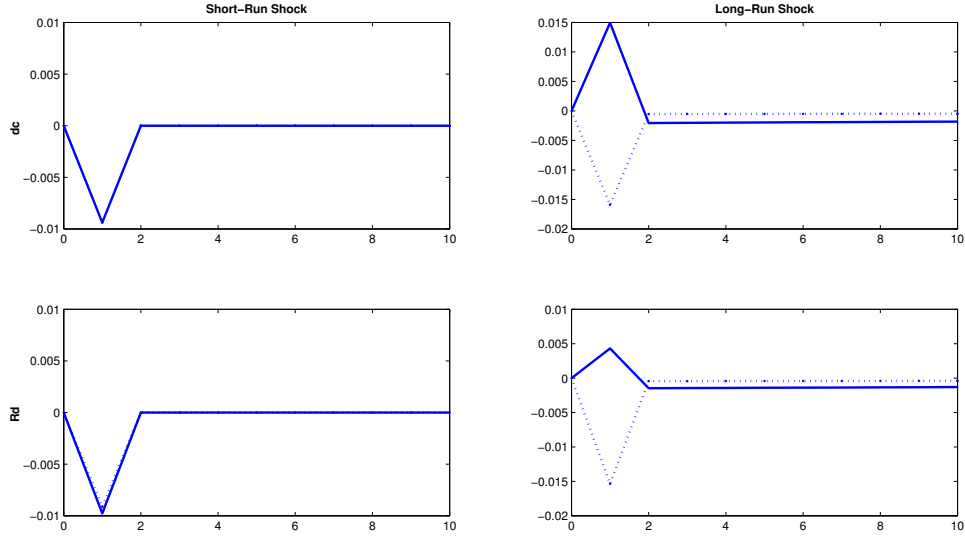


Figure 17: **Impulse response functions with long-run risk and partial economic integration.** This figure presents the impulse response functions of consumption growth ( $dc$ ) and stock market return ( $Rd$ ) for both the home (solid line) and foreign country (dashed line). All parameters are calibrated to the values reported in table 1. The consumption home bias parameter,  $\alpha$ , is 0.75 and denotes partial economic integration. Impulse response functions are based on specification (3a) in table 5. A negative  $\sigma_x$  shock in the short-run, and a negative  $\sigma$  shock in the long-run materialize only in the home country, and only at time 1.

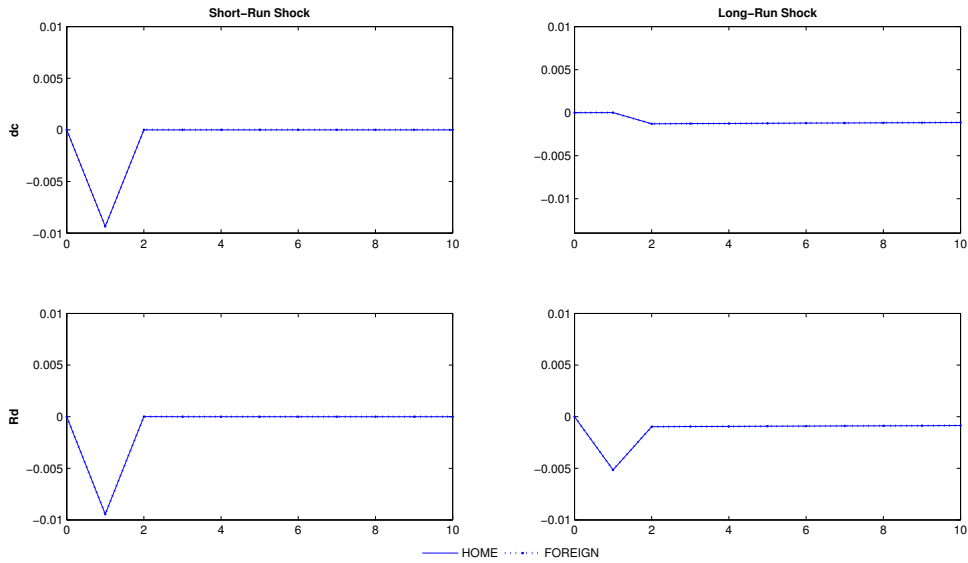


Figure 18: **Impulse response functions with long-run risk and full economic integration.** This figure presents the impulse response functions of consumption growth ( $dc$ ) and stock market return ( $Rd$ ) for both the home (solid line) and foreign country (dashed line). All parameters are calibrated to the values reported in table 1. The consumption home bias parameter,  $\alpha$ , is 0.5 and denotes full economic integration. Impulse response functions are based on specification (4a) in table 5. A negative  $\sigma_x$  shock in the short-run, and a negative  $\sigma$  shock in the long-run materialize only in the home country, and only at time 1.