FOREIGN DIRECT INVESTMENT AS A DETERMINANT OF CROSS-COUNTRY STOCK MARKET COMOVEMENT*

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Abstract. We develop a theoretical framework in order to investigate the link between two recent trends: (i) the rise in cross-country stock market correlations over the past three decades, and (ii) the increase in global foreign direct investment (FDI) positions over the same period. Our objective is twofold: first, we investigate empirically the channel through which the rise in global stock market correlations is associated with the observed increase in global FDI. Second, we develop a two-country stochastic asset pricing model with multinational firms that allows us to quantify the extent to which the recent rise in global FDI can account for the observed increase in cross-country stock market comovement. Calibrating three versions of the model (financial autarky, incomplete markets and complete markets) to the US and the rest-of-the-world, we find that a permanent inrcease in FDI positions, as observed from mid 1990s to mid 2000s, leads to substantial increase in cross-country stock market comovements. Increases in FDI alone can account for approximately one third of the observed increase in stock market correlations. We also discuss the role of portfolio diversification and, more generally, asset market integration.

Keywords: stock market comovements, foreign direct investment, business cycle synchronisation, multinational firms, asset pricing

JEL Classification: G15, F21, F23, G12, F44

1. Introduction

In the post WW2 period, the cross-country correlations of the stock markets in developed economies ware fairly low, implying significant potential benefits from diversification. Beginning in the mid 1990s, stock market correlations started increasing and continued to do so up until the aftermath of the Great Recession. These increases have been quantitative large; for example the correlation of US equity prices with the equity prices in an aggregate of 22 other developed economies has risen from below 0.40 in the 1980s to above 0.80 in the 2010s. Although the size and timing of this increase varies to some extent, a similar pattern can be found when looking at bilateral country pairs. The increase in stock market correlations has largely coincided with a concurrent strengthening in foreign direct investment (FDI) linkages between the largest economies with developed equity markets. The

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aim of this paper is to explore the relationship between these two facts. We first document these two phenomena and establish an empirical relation between them that survives after controlling for other potentially important factors such as increased trade, and business cycles synchronization. We subsequently provide a theoretical framework that can be used to clarify the mechanism that links the two phenomena, but also to quantify the contribution of FDI changes to the increase in stock market correlations. We find that the increase in FDI positions can explain approximately one third of the increase in the cross-country stock market comovements.

We develop a two-country production-based asset pricing model which, crucially, incorporates multinational firms investing in technology capital. The mechanism we propose is simple. Multinational corporations operate plants in both countries and that implies that they are exposed to shocks in both the home and foreign country. In an environment with increased FDI, firms generate a larger fraction of their earnings abroad. In turn, this implies stronger incentives to increase investment in response to shocks in the foreign country. Increased investment in technology capital also spills over to investment at home, due to the complementarity between tangible and technology capital. The end result is that investment and capital are more synchronized across multinationals and this implies their equity values are also more correlated.

The structure of international financial markets can be important for the extent to which equity prices are synchronized. In our benchmark model we assume markets are incomplete, but we also consider the implications of complete markets and, at the other extreme, financial autarky. We show that the *level* of stock market correlations increases as markets become more complete, as expected. However, the *increase* in stock market correlations when FDI linkages increase is present regardless of the asset market structure. Importantly, this is despite very different implications for the correlation of dividends across market structures. The model allows us to separate and explore different channels via which stock markets may comove. First we examine whether the rise in stock market correlation comes from a combination of increased FDI and asset market integration, and the interaction between those two. Additionally, we consider the channel of international portfolio diversification, and show that in our model an increase in portfolio diversification alone cannot provide an explanation for the increase in stock market correlation.

Our work relates to several distinct literatures. The empirical observation that cross-country stock market correlations have recently increased has been documented in a number of papers. Goetzmann, Li and Rouwenhorst (2005) document the variation in the correlation structure of world equity markets over the span of the last 150 years. They show that the correlations of the major equity markets increased in the last two decades and argue that the potential for international diversification in recent times is quite low compared to the earlier history of capital markets. Along the same lines, Quinn and Voth (2008) argue that while stock market correlations among major developed economies were roughly constant until the late 1980s, there has been a dramatic increase in correlations starting early 1990s due to greater capital market openness. Claessens, Kose and Terrones (2011) document the fact that cross-country stock market correlations have been increasing since the late 1980s, and contrast this finding to the fact that there has been no notable change in the cross-country correlations of credit and house prices. Corroborating this result, in a recent paper, Jorda, Schularick, Taylor and Ward (2019) document that there has been a rapid increase in global synchronization of equity prices since the 1990s and argue that it has reached historically unprecedented levels, exceeding substantially the increase in the comovement of other financial variables. This fact is also highlighted in Cho and

Tsiaras (2019).

Even though there is a vast number of papers focusing on the determinants of international business cycle comovements, the literature seems to be inconclusive. The most prominent explanations explored in the literature are international trade (Baxter and Kouparitsas 2005), financial integration (Imbs 2004, 2006) and economic integration (Kalemli-Ozcan, Papaioannou, and Peydro, 2013 and Kalemli-Ozcan, Papaioannou, and Perri, 2013). In contrast, there are several studies that argue that trade and financial openness are not that important. Crosby (2003) and Imbs (2001) find that the contribution of trade to the international business cycle comovements is negligible. Kalemli-Ozcan, Papaioannou, and Peydro (2013) and Kalemli-Ozcan, Papaioannou, and Perri (2013) identify a strong negative effect of banking integration on global output synchronization. In line with these studies, Menno (2017) finds that while financial integration and international trade took off over past three decades, there has been no noticeable increase in GDP correlations. Jorda, Schularick, Taylor and Ward (2019) evaluate the comovements of real and financial variables using historical data, starting in 1870. They find that GDP comovement in early 2010s at its highest level since the late 19th century, and that consumption comovements change on a par with GDP comovements. Interestingly, they also find that investment comovement has also reached a peak in 2000s, a result also highlighted in Menno (2017), who finds that there has been a significant increase in investment correlations over the same period of interest as in this paper. These findings are in line with the prediction of our theoretical model that higher FDI openness leads to an increase in both investment and stock price correlations, without having significant effects on output correlations.

The literature on FDI is extensive and still expanding; see Helpman, Melitz and Yeaple (2004), McGrattan and Prescott (2009), (2010), Kapicka (2012), Ramondo and Rodriguez-Clare (2013), Ramondo (2014) among others. Antras and Yeaple (2014) provided a detailed review of various modeling approaches on FDI. Yet the literature that focuses on the role of multinational corporations in the transmission of international business cycle shocks is small and quite recent. By focusing on US multinationals and their foreign affiliates in Mexico, Burstein, Kurz and Tesar (2008) first investigate the empirical link between FDI activity and bilateral business cycle movements and then develop a theoretical model (extending Backus, Kehoe and Kydland, 1995) in order to quantify to what extend this link can be theoretically explained. Cravino and Levchenko (2017) investigate the same link, i.e. how multinationals contribute to the transmission of business cycle shocks, using a more extensive multi-country firm level data. They find that the most integrated countries are significantly more affected by foreign shocks. They build a parsimonious model based on Melitz (2003) to interpret their findings. In line with this literature, our model extends the framework proposed by McGrattan and Prescott (2010), Kapicka (2012), and Anagnostopoulos and Atesagaoglu (2019), by (i) incorporating stochastic shocks and (ii) modeling explicitly the stock markets and prices in the two countries.

Finally, our work is broadly placed in the large literature that studies international business and financial cycles comovement (both empirical and theoretical). This literature is mature (seminal papers include Backus, Kehoe and Kydland (1995), Baxter and Kouparitsas (2004)) but also has important more recent contributions, including di Giovanni and Levchenko (2010), Kalemli-Ozcan, Papaioannou, and Peydro (2013), Kalemli-Ozcan, Papaioannou, and Perri (2013) and Cesa-Bianchi, Imbs, Saleheen (2019). Our paper contributes to that literature by incorporating technology/intangible capital into a two-country international business cycle model and investigating its implications.

The paper is organized as follows: the next section gives some empirical motivation for the paper and explains some basic facts about stock market and FDI comovements. Section 3 describes the model with production and multinational firms. Sections 4 and 5 present the numerical results for the main FDI experiment and the extension to portfolio diversification. Section 6 provides some more detailed empirical support to the link between stock market correlations and FDI positions and the last section summarizes and concludes.

2. Stylized Facts

Historically, the correlation between international stock markets had been fairly low (less than 50% on average), providing significant diversification benefits. However, this pattern started to change in the mid-1990s. Over the past two decades, global stock markets have steadily become more correlated; this fact has been identified in different contexts in several papers, e.g. Bekaert and Harvey (2000), Quinn and Voth (2008) and recently Jorda, Schularick, Taylor and Ward (2019). Here we provide evidence showing this increase in correlations that is consistent with those studies and, at the same time, evidence on the increase in FDI linkages. The evidence provided suggests a potential link between the two phenomena.

Starting with stock markets, our data consists of MSCI indices for a number of developed economies with large and well functioning stock markets. We work with two sets of indices. We first look at the stock markets in the US, and compare to the rest of the world, for which we use MSCI US and MSCI World excl. US.[1] Second, we also look at correlations of MSCI indices of bilateral pairs of six large economies with large stock markets: United States (US), Canada (CA), Japan (JN), United Kingdom (UK), France (FR) and Germany (DE).[2] We use the MSCI indices in weekly frequency to first calculate weekly returns for a country i at the end of week t as

$$r_{it} = \frac{MSCI_{it} - MSCI_{i,t-1}}{MSCI_{i,t-1}} \tag{1}$$

and then calculate a measure of correlation $SMC_{ij,t}$ between the stock markets of two countries i and j at time t, using the following definition

$$SMC_{ij,t} = corr\left(\mathbf{r}_t^i, \mathbf{r}_t^h\right), \tag{2}$$

where $\mathbf{r}_t^i = \left(r_{t-w/2}^i, ..., r_{t+w/2}^i\right)$, with w a pre-specified time 'window'. Using a rolling window of $w = 208$ weeks (four years), Figure 1 shows correlations between US and rest of the world. Each point reported in this graph is therefore dated in the middle of the rolling window used for calculating the reported correlation, e.g. $SMC_{ij,(1/1/1990)}$ is the correlation of weekly returns for the range 1/1/1988 to 31/12/1991. Looking at the figure, it becomes apparent that there has been a substantial upshift in the correlation starting in the mid 1990s and continuing to late 2000s. The average correlation for the decade 1986 to 1995 is 0.37 and the one for 2004 to 2013 is 0.82. Figure 2 shows the same measure of bilateral stock market correlations between the six countries listed above and confirms the observation that cross-country stock market correlations have been increasing in the past three decades.

[1] The MSCI World excl. US consists of the following 22 countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hong Kong, Ireland, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland and the UK.

[2] Our choice of countries is restricted mostly by availability of data on FDI positions. Importantly, the six countries we look at have very large stock markets, that account for the majority of stock market activity across the world.

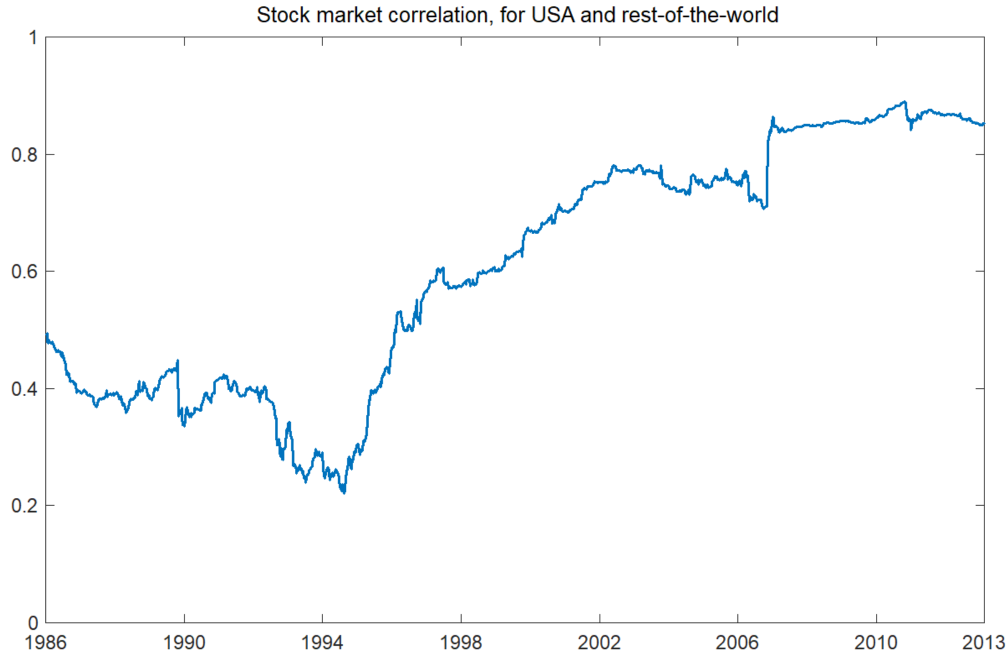

Figure 1: Stock market correlation, SMC(US, ROW). Calculated over four year rolling windows, using weekly MSCI US and MSCI World Exc. US. Data range 1/1/1984 - 31/12/2015.

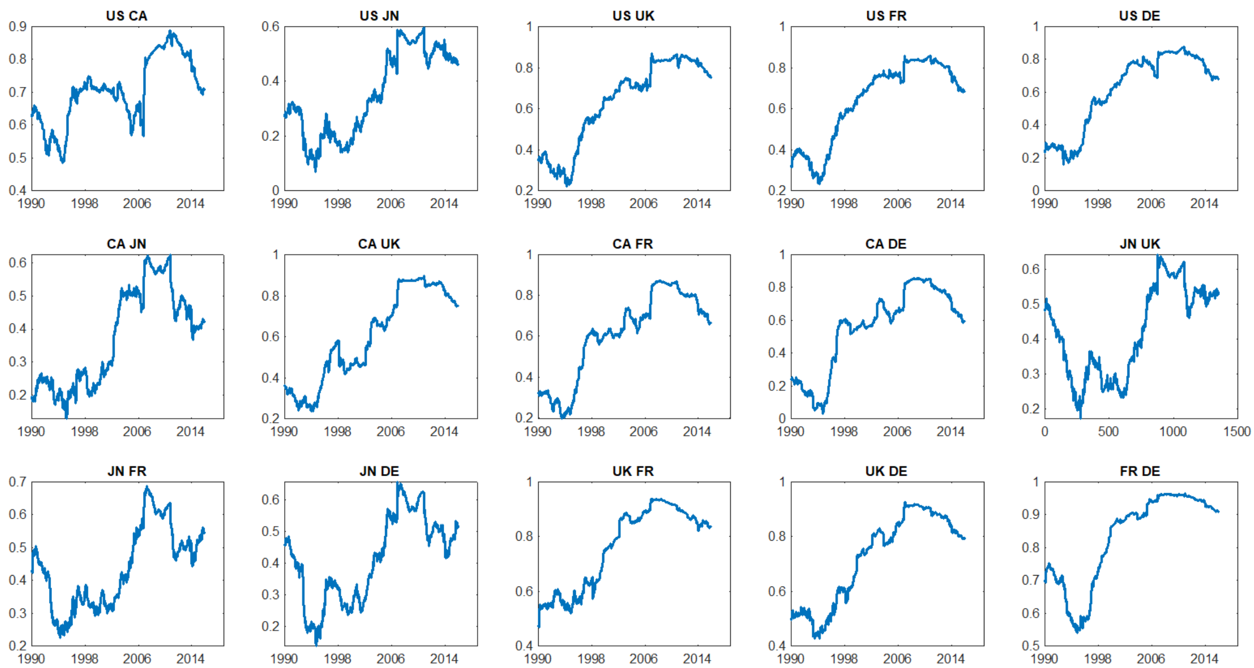

Figure 2: Stock market correlations, bilateral, between United States (US), Canada (CA), Japan (JN), United Kingdom (UK), France (FR), Germany (DE).

What drives the observed rise in global stock market correlations? Here we explore the relationship between the rise in global stock market correlations and FDI activity, and as a first pass we look at how FDI between the same pairs of countries has changed in the last 30 years. The equity price of a multinational firm is determined by its earnings generated all over the world. Since the earnings of a foreign subsidiary are directly affected by the business cycles of the countries that it operates in, as multinationals increase their overseas investment, they will be affected more from cross-border business cycles. Therefore changes in international stock market correlations may be related to changes in FDI activity between countries. With this intuition in mind, we next construct a measure of correlations of FDI positions between the six countries of interest.

Our measure of FDI activity between two countries i and j at the start of a given year t, is defined relative to the size of the two economies:[3]

$$RF_{ij,t} = \frac{FDI^{j}_{i,t} + FDI^{i}_{j,t}}{GDP_{i,t} + GDP_{j,t}}, \tag{3}$$

where $FDI^{j}_{i,t}$ is the nominal FDI position of country j in country i, $FDI^{i}_{j,t}$ is the nominal FDI position of country i in country j, and $GDP_{i,t}$ and $GDP_{j,t}$ denote the nominal GDPs of the two countries, all reported in US dollars.

Figure 3 shows the measure of relative FDI, RF, between US and the rest of the world, plotted together with the corresponding SMC measure. In the figure, the left hand vertical axis shows the scale for SMC and the right hand axis shows the scale for RF, expressed in percent. We see that during the 1980s and well into the 1990s, the FDI of US relative to world GDP was stable and around 5%, and then increases steadily for a few years, until it doubles to a permanent higher level of approximately 10%. During the period from mid 1990s to early 2000s, we observe an increase in relative FDI, and at the same time a dramatic increase in the stock market correlation measure.

Turning to specific country pairs, we use bilateral FDI positions from *OECD Foreign Direct Investment Database* at a yearly frequency. OECD has recently revised the definition of FDI and provides a new series from 2013 onwards, which unfortunately causes a break in the series after 2012.[4] For this reason we restrict our data and analysis up to and including 2012. Theoretically, the outward FDI position of country i in country j should be equal to the inward FDI position of country j in country i. However, because countries may have different ways of reporting inward and outward FDIs, these two statistics are mostly different. Moreover, for Japan, there are some missing data values, and for France, FDI inward and outward position data only starts in 1998. For these reasons, we use the best and longest available measured version of FDI position between the two countries. We have done the analysis for a variety of alternative combinations and find the same qualitative features of FDI positions in the last 2.5 decades. With a few exceptions, the pattern we observe for the bilateral relative FDIs is the same as that for the US and the rest of the world. They appear to be increasing at around the same period as the corresponding shifts in stock market correlations. For many of these pairs, the shift up occurs around mid 1990s. These increases seem to take place at around the same time that the corresponding stock market correlations increase, as shown in Figure 4.

[3] We follow Kalemli-Ozcan, Papaioannou, and Perri (2013) and Menno (2017) who define FDI linkages similarly.
[4] See OECD Benchmark Definition of Foreign Direct Investment, 4th Edition (BMD4).

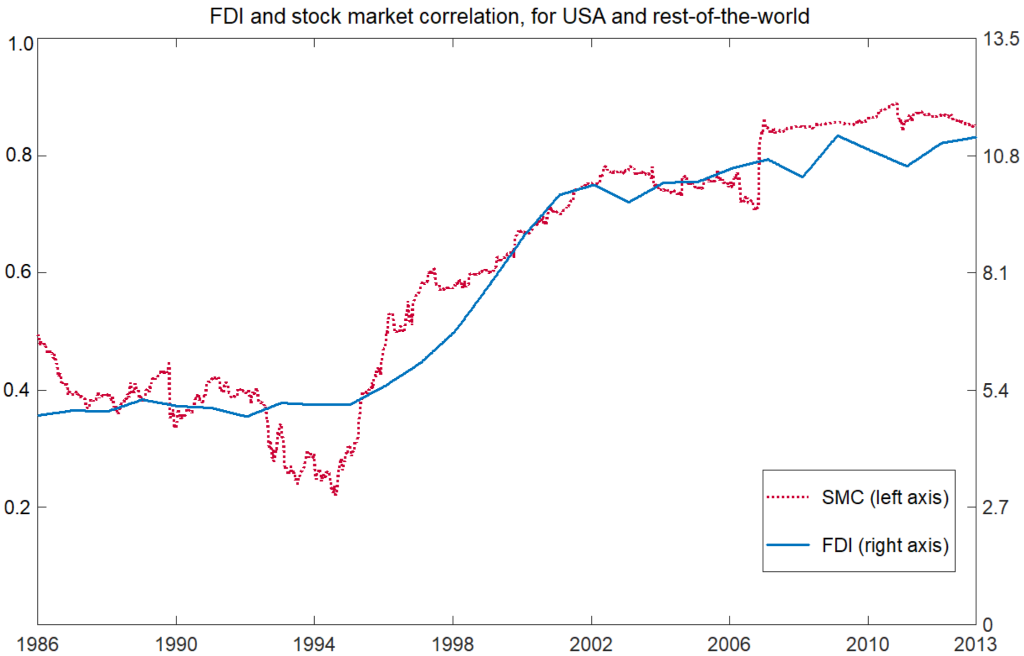

Figure 3: Stock market correlation and relative FDI, for the US and the rest of the world. FDI data source: *FRED*. The dotted line, scale on left axis, is $SMC_{US,ROW}$. The solid line, scale on right axis, is $RF_{US,ROW}$ expressed in %.

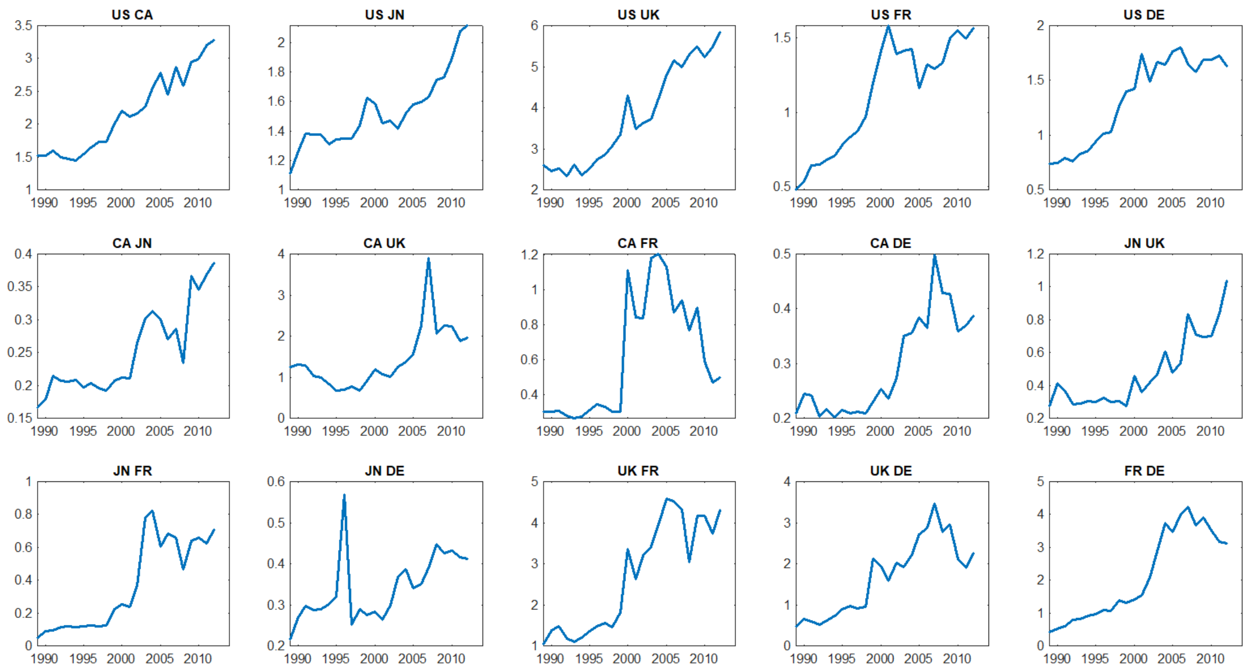

Figure 4: Bilateral relative FDIs, between United States (US), Canada (CA), Japan (JN), United Kingdom (UK), France (FR), Germany (DE), all expressed in %. Data in annual frequency, source: *OECD*.

3. The model

Our model extends the framework of McGrattan and Prescott (2009, 2010), also used by Kapicka (2012), McGrattan (2012), and Anagnostopoulos and Atesagaoglu (2019), by adding country-specific productivity shocks and capital adjustment costs. Time is discrete and infinite, indexed by $t = 0, 1, 2, ...$ There are two countries, each one populated by a representative household, and two multinational firms. Each multinational firm operates two productive units (plants), one located within the country where the multinational is incorporated and one located abroad. Thus, there are four plants overall. In what follows, superscripts $h = 1, 2$ are used to denote the multinational that *owns* the plant and subscripts $i = 1, 2$ are used to denote the country in which the plant is *located*. We assume that firm h is incorporated in country h. Upper case letters denote aggregate variables within each country.

3.1. Firms. Consider the plant located in country i and owned by multinational firm h. At any time t, the plant's output is denoted by Y_{it}^h. The physical capital stock and labour used for production are denoted by K_{it}^h and N_{it}^h respectively. Each multinational also has technology capital M_t^h which is used as an additional input to production in both of its plants (hence no i subscript). The production function for firm h in country i at time t is

$$Y_{it}^h = A_i Z_{it} \sigma_i^h F(\upsilon_i M_t^h, K_{it}^h, N_{it}^h), \quad i, h = 1, 2, \tag{4}$$

where A_i is a productivity parameter, Z_{it} denotes a country-specific total factor productivity (TFP) shock and the σ_i^h are parameters governing the degree of openness of each country i. We assume $\sigma_1^1 = \sigma_2^2 = 1$ so that $\sigma_1^2, \sigma_2^1 \in [0, 1]$ can be used to control the amount of production by the foreign multinational relative to the home multinational in country i. The parameter σ_i^h reflects exogenous reasons for which multinational h may be prevented from producing at location i, such as legislation. The parameter υ_i captures both the amount of locations/plants operating in country i as well as the population size in country i, as in McGrattan and Prescott (2009).

Physical capital and technology capital accumulation are described by

$$K_{it+1}^h = (1-\delta_K)K_{it}^h + X_{K,it}^h - \Phi\left(\frac{X_{K,it}^h}{K_{it}^h}\right)K_{it}^h, \ i, h = 1, 2, \tag{5}$$

$$M_{t+1}^h = (1-\delta_M)M_t^h + X_{M,t}^h - \Phi\left(\frac{X_{M,t}^h}{M_t^h}\right)M_t^h, \ h = 1, 2, \tag{6}$$

where $X_{K,it}^h$ and $X_{M,t}^h$ are investment in physical and technology capital respectively, δ_K, δ_M are depreciation rates and Φ represents the capital adjustment cost function, in line with Hayashi (1982).

The multinational incorporated in country h maximizes the discounted value of worldwide dividends D_t^h

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \Psi_{0,t}^h D_t^h,$$

where $\Psi_{0,t}^h$ is the stochastic discount factor used by the firm. Dividends D_t^h are given by

$$D_t^h = Y_{1t}^h + Y_{2t}^h - W_{1t}N_{1t}^h - W_{2t}N_{2t}^h - X_{K,1t}^h - X_{K,2t}^h - X_{M,t}^h. \tag{7}$$

3.2. Households. The representative household in each country i maximizes expected lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u\left(c_{it}, n_{it}\right), \tag{8}$$

where c_{it}, n_{it} represent a household's consumption and labor supply respectively, and the instantaneous utility satisfies standard assumptions. Each country i is populated by υ_i identical individuals so that aggregate consumption in country i is $C_{it} \equiv \upsilon_i c_{it}$ and aggregate supply of labour to the plants that operate domestically is $N_{it} \equiv \upsilon_i n_{it}$. Households earn a wage W_{it} and can buy and sell shares of the domestically incorporated firm only (perfect home bias). The number of shares bought by each household at time t is denoted by θ_{it+1} and the price at which they are bought is denoted by P_t^i. The aggregate number of shares bought at time t in country i is $\Theta_{it+1} \equiv \upsilon_i \theta_{it+1}$. As a benchmark we make the assumption that markets are incomplete (IM) and allow households to only trade a non-contingent bond b_{it} across countries. The budget constraint is then

$$c_{it} + P_t^i \theta_{it+1} + P_{b,t} b_{it+1} + \frac{\chi}{2} b_{it+1}^2 = W_{it} n_{it} + \left(D_t^i + P_t^i\right) \theta_{it} + b_{it}. \tag{9}$$

Bond holdings are subject to a quadratic cost, which ensures that the solution to the model will be stationary and can be used to vary the level of market incompleteness in our experiments below.

We also consider the two extreme financial market structures, namely financial autarky (FA) and complete markets (CM). In the first extreme of financial autarky, we do not allow any cross-country trade in financial assets by households. The budget constraint for a household is

$$c_{it} + P_t^i \theta_{it+1} = W_{it} n_{it} + \left(D_t^i + P_t^i\right) \theta_{it}. \tag{10}$$

At the other extreme, under complete markets, households can trade a full set of state contingent claims

$$c_{it} + P_t^i \theta_{it+1} + \int q_t\left(s^t, \bar{s}\right) b_{it+1}\left(s^t, \bar{s}\right) d\bar{s} = W_{it} n_{it} + \left(D_t^i + P_t^i\right) \theta_{it} + b_{it}\left(s^{t-1}, s_t\right), \tag{11}$$

where s^t denotes the history of shocks $\left(Z_1^t, Z_2^t\right)$, $b_{it}\left(s^{t-1}, s_t\right)$ is the number of contingent claims bought in the previous period at state s^{t-1} and promising to pay at state $s^t = \left(s^{t-1}, s_t\right)$ today and $q_{t-1}\left(s^{t-1}, s_t\right)$ is the corresponding price.

Under complete markets, the marginal rate of substitution of the household is equalized across all households (of both countries), and defines the stochastic discount factors for both firms. When markers are not complete, since we have assumed perfect home bias, the stochastic discount factor of firm h corresponds to the intertemporal marginal rate of substitution of the representative household in country h.

3.3. Aggregation and market clearing. Labor markets clear in each country, i.e. the aggregate supply of labour equals the demand for labour from each of the two firms:

$$N_{it} \equiv \upsilon_i n_{it} = N_{it}^1 + N_{it}^2,\ i = 1, 2. \tag{12}$$

Parameter	Value	Target	Source
Relative Population υ_2/υ_1	2.16	-	PWT, 1991-1995
Relative Productivity A_2/A_1	0.822	Relative GDP	PWT, 1991-1995
Investment adj. costs ϕ	depends on economy	$\frac{\sigma(X_K)}{\sigma(Y)} = 2.39$	Boldrin et al (2001)
Depreciation of tech capital δ_M	0.020	-	McGrattan, Prescott (2010)
Depreciation of physical capital δ_K	0.021	$X_K/Y_K = 0.14$	BEA 1982-1995
Labour share α_N	0.636	$WN/Y = 0.636$	BEA 1982-1995
Tangible Capital Share α_K	0.276	$M/K = 0.33$	Kapicka (2012)
Tech Capital Share α_M	0.088	$1 - \alpha_K - \alpha_N$	$1 - \alpha_K - \alpha_N$
Discount Factor β	0.979	$K/Y = 6.8$	BEA 1982-1995
Openness parameter (before) σ_1^2	0.7924	$K_1^2/K_1^1 = 0.12$	Flow of Funds 1991-1995
Openness parameter (before) σ_2^1	0.8402	$K_2^1/K_1^1 = 0.15$	Flow of Funds 1991-1995
Openness parameter (after) σ_1^2	0.8774	$K_1^2/K_1^1 = 0.31$	Flow of Funds 2011-2015
Openness parameter (after) σ_2^1	0.9208	$K_2^1/K_1^1 = 0.50$	Flow of Funds 2011-2015

Table 1: Baseline calibration.

The aggregate supply of shares of each firm is normalized to one and the stock market clears in each country

$$\Theta_{it} \equiv \upsilon_i \theta_{it} = 1,\ i = 1, 2. \tag{13}$$

Additionally, under incomplete markets, we assume that bonds are in zero net supply and the world bond market clears:

$$\text{IM: } B_{1t+1} + B_{2t+1} = 0. \tag{14}$$

where $B_{it+1} \equiv \upsilon_i b_{it+1}$ denotes aggregate bonds bought at time t by individuals in country i. Finally, under complete markets, the contingent claims markets clear

$$\text{CM: } B_{1t+1}\left(s^t, \bar{s}\right) + B_{2t+1}\left(s^t, \bar{s}\right) = 0 \text{ for all } \bar{s} \text{ and all } s^t. \tag{15}$$

Regardless of asset market structure, the following world aggregate resource constraint holds

$$\sum_{i=1}^{2} C_{it} + \sum_{h=1}^{2}\left(X_{K,1t}^h + X_{K,2t}^h + X_{M,t}^h\right) = \sum_{i=1}^{2}\sum_{h=1}^{2} Y_{it}^h. \tag{16}$$

4. Numerical Results

4.1. Calibration. We calibrate the model to match long run ratios based on US data and only make countries asymmetric with respect to the levels of GDP and population sizes and the fraction of firm tangible capital installed in the foreign plant (FDI). The calibration frequency is quarterly and the full set of parameters, targets and sources is summarized in Table 1. With respect to preferences, we assume an instantaneous utility function that is of the standard CRRA form and that labor supply is inelastic:

$$u\left(c_{it}, n_{it}\right) = \frac{c_{it}^{1-\theta}}{1-\theta}. \tag{17}$$

In the benchmark calibration we set the coefficient of relative risk aversion θ to 1.

The production of multinational h in country i is represented by the following Cobb-Douglas technology

$$Y_{it}^{h} = A_i Z_{it} \sigma_i^h (\upsilon_i M_t^h)^{\alpha_M} (K_{it}^h)^{\alpha_K} (N_{it}^h)^{\alpha_N}, \tag{18}$$

where α_K, α_M and α_N denote, respectively, the income shares of tangible capital, technology capital and labor, $0 < \alpha_K, \alpha_M, \alpha_N < 1$ and $\alpha_K + \alpha_M + \alpha_N = 1$. The income shares along with the depreciation rates δ_K, δ_M and the discount factor β are calibrated as follows.[5] Using NIPA data for the US corporate sector between 1982 and 1995, we compute the average labor share to be $\alpha_N = 0.636$ and the ratio of corporate tangible investment to corporate GDP to be 0.14 on average, which pins down δ_K. We follow McGrattan and Prescott (2010) and Kapicka (2012) in setting the depreciation rate for technology capital to 8% annually, so that $\delta_M = 0.02$. Using Fixed Asset Tables, we calculate the tangible capital to output ratio in the corporate sector to be 6.8 for the same years and use the discount factor to target this in our benchmark economy. The relative size of technology to tangible capital is estimated to be approximately 0.33 in Kapicka (2012) and this can be matched by choosing $\alpha_K = 0.276$ in our model.

For the population sizes υ_i and TFP parameters A_i we normalize the US values to one, i.e. $\upsilon_1 = A_1 = 1$. We then take country 2 to be the rest of the world, as defined by the set of countries which are included in the MSCI ex. US index.[6] Using OECD data for the years 1991-1995 we find that the population of these countries is 2.16 times the US population and thus set $\upsilon_2 = 2.16$. We also find the sum of the GDPs of these countries to be 1.75 times that of the GDP of US, and therefore calibrate $A_2 = 0.822$ to match the relative GDPs.

Capital adjustment costs are commonly used in international macro models to avoid excessive investment volatility. Accordingly, in our model, tangible and technology capital are subject to adjustment costs and we assume that

$$\Phi(x) = \frac{\phi}{2}(x - \delta)^2, \tag{19}$$

where the adjustment cost parameter ϕ is calibrated to match the observed standard deviation of tangible capital investment relative to the standard deviation of output for the US economy. We target the value of 2.39 for this ratio, reported by Boldrin, Christiano and Fisher (2001).[7]

Turning to the productivity shocks, we follow Backus, Kehoe and Kydland (1992), Baxter and Crucini (1995) and Kehoe and Perri (2002), and assume that the shocks (Z_{1t}, Z_{2t}) follow a vector autoregressive (VAR) process of the form

$$\begin{bmatrix} \log(Z_{1t+1}) \\ \log(Z_{2t+1}) \end{bmatrix} = \begin{bmatrix} \rho_1 & \rho_2 \\ \rho_2 & \rho_1 \end{bmatrix} \begin{bmatrix} \log(Z_{1t}) \\ \log(Z_{2t}) \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t+1} \\ \varepsilon_{2t+1} \end{bmatrix}. \tag{20}$$

The innovations $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})$ are serially independent, multivariate normal random variables. Following the estimates of Baxter and Crucini (1995) and Kehoe and Perri (2002), we set the persistence parameter ρ_1 to 0.95 and the spillover parameter ρ_2 to 0. Based on the same set of papers, we set the

[5]As pointed out by McGrattan and Prescott (2010) domestic production in the model has to be adjusted by subtracting technology investment to match to measured GDP in the BEA data. We carefully make this adjustment when computing our targets in the model.

[6]The rest of the world list of countries excludes Hong Kong and Singapore due to data limitations.

[7]The adjustment cost parameter value has to be adjusted to obtain the same target for each of the three economies we consider (FA, IM and CM). All other parameter values remain the same since these economies share the same steady state ratios.

Incomplete Markets	FDI_{low}	FDI_{high}
$corr(P^1, P^2)$	0.382	0.525
$corr(X^1, X^2)$	0.383	0.527
$corr(K^1, K^2)$	0.368	0.506
$corr(D^1, D^2)$	0.139	-0.336
$corr(C_1, C_2)$	0.365	0.459
$corr(GDP_1, GDP_2)$	0.250	0.249
$corr\ (X_{K,1}, X_{K,2})$	0.372	0.448

Table 2: Correlations of stock prices, total firm investment, total firm capital, firm dividends, country consumptions, GDP and country tangible capital investment

correlation of the innovations to $corr(\varepsilon_{1t}, \varepsilon_{2t}) = 0.25$ but also consider a case where $corr(\varepsilon_{1t}, \varepsilon_{2t}) = 0$ in our discussion of results.

We calibrate the openness parameters σ_1^2, σ_2^1 to capture respectively the FDI position in the US and the US direct investment position abroad first in the early 1990s (before) and then for early 2010s (after). For this, we use Fed Board Flow of Funds data, and find that the ratio of FDI position in the US to the tangible capital stock owned by US corporations in the US was $K_1^2/K_1^1 = 0.12$ on average during 1991-1995. For the same period, we find that the ratio of US direct investment position abroad to the tangible capital stock owned by US corporations in the US was $K_2^1/K_1^1 = 0.15$. We match these two quantities in our benchmark calibration by choosing $\sigma_1^2 = 0.7924$ and $\sigma_2^1 = 0.8402$. In our main experiments we then change these values to $\sigma_1^2 = 0.8774$ and $\sigma_2^1 = 0.9208$, which imply the capital ratios change to $K_1^2/K_1^1 = 0.31$ and $K_2^1/K_1^1 = 0.50$ matching the corresponding numbers in the data for the years 2011-2015.

Our benchmark economy is that with incomplete markets, for which there is an additional parameter to be calibrated, namely the bond trade cost parameter χ. This controls the amount of risk sharing that households can achieve internationally through the trade of bonds. In turn, the level of risk sharing will affect the cross-country correlation of consumption and, by implication, the level of stock market comovement. We choose χ to match a cross-country correlation of aggregate consumptions. We compute this to be 0.36 by averaging the correlations between US consumption and consumption of each of the countries in the MSCI index, using OECD data between 1962 and 2014.[8] This number falls within the range of estimates obtained in the literature based on a variety of choices for countries and periods (e.g. Backus, Kehoe, Kydland, 1992 and 1995; Kehoe and Perri, 2002; Heathcote and Perri, 2002; Ambler, Cardia, Zimmermann, 2004; Bengui, Mendoza, Quadrini, 2013). This value of consumption correlation implies a stock market correlation of 0.38, which is remarkably close to the average for the years 1986-1995 computed in our data.

4.2. Results. Our baseline experiment consists of exogenously increasing the openness parameters to match the increase in FDI positions observed in the data as explained in the previous section and using the model to obtain the implied increase in stock market correlations. Table 2 presents correlations of stock prices and other key variables in the economy before and after the changes in σ, using the calibrated values $\sigma_1^2 = 0.7924$, $\sigma_2^1 = 0.8402$ (before) and $\sigma_1^2 = 0.8774$ and $\sigma_2^1 = 0.9208$ (after). Moments are generated by a simulation of 100,000 periods of the first order approximation of the model, from which we drop the first 1,000 periods and then take averages. All series are HP

[8] This calculation excludes Hong Kong and Singapore, due to data limitations.

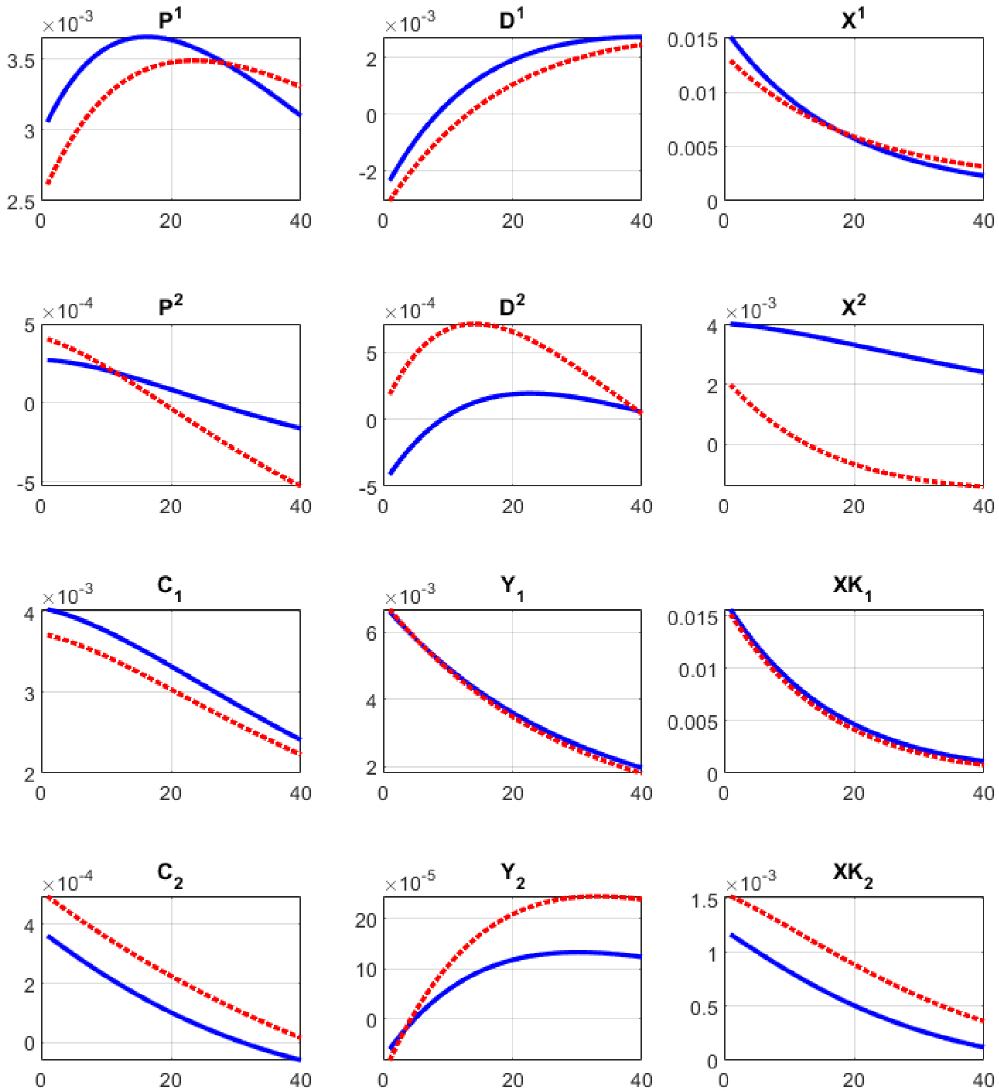

Figure 5: Impulse response functions, under IM. Shock to TFP of country 1. Blue solid line generated using σ_{lo}, red dotted line generated using σ_{hi}.

filtered with a smoothing parameter of 1600, given that our calibration is for quarterly data. In our benchmark calibration with incomplete markets, the correlation of stock prices is 0.38 before the FDI increase and it increases to 0.52 after the increase. In the data the correlation increases from 0.37 to 0.82. Thus the FDI channel alone explains approximately *one third* of the stock market correlation increase.

To understand stock price comovement, it is helpful to relate the equilibrium stock price of a firm to its capital stock and investment. In Appendix A, we derive the following condition

$$P_t^h = \frac{1}{1-\Phi'\left(X_{K,1t}^h/K_{1t}^h\right)}K_{1t+1}^h + \frac{1}{1-\Phi'\left(X_{K,2t}^h/K_{2t}^h\right)}K_{2t+1}^h + \frac{1}{1-\Phi'\left(X_{M,t}^h/M_t^h\right)}M_{t+1}^h, \quad (21)$$

which expresses the ex-dividend value of firm h as a weighted sum of its capital stocks. In a standard RBC model with no FDI and no technology capital, there is only one capital stock and it is valued at a price q arising from the presence of adjustment costs just like in this model. This is commonly referred to as Tobin's q. Here, similar capital stock valuations arising from adjustment costs are derived, but they can potentially be different for the different types of capital. As is standard, these capital stock valuations arise due to adjustment costs and are increasing in the investment rates of the corresponding capitals.

In the absence of adjustment costs, (21) simply states that the value of the firm is equal to the its total capital $K_{t+1}^h = K_{1t+1}^h + K_{2t+1}^h + M_{t+1}^h$ and stock prices move exactly in tandem with the total capital stocks of the firms. Here, adjustment costs are used to reduce the variability of the capital stocks. In this case, stock price variations also depend on the variation in the valuations, which are increasing functions of investment rates. Motivated by this equilibrium relation, and noting that to a first order approximation, the stock price of a firm is the weighted average of the total capital stock and the total investment of the firm, we can then relate the correlation of stock prices to the comovement of the *total capital stocks*, as well as the comovement of the *total investment* of the two firms

$$X_t^h \equiv X_{K,1t}^h + X_{K,2t}^h + X_{M,t}^h. \quad (22)$$

Table 2 illustrates that correlations of investment are very similar to the correlations of the capital stocks and both are very similar to the correlations of stock prices. Therefore, potentially high stock price comovement can be attributed to more synchronization of investment across the two multinationals. Guided by this observation, we can see how stock prices tend to comove when foreign firms are exposed to domestic shocks through FDI. A persistent increase in home TFP induces the foreign multinational to increase its investment at the same time as the home multinational, because its foreign plant is now expected to be temporarily more productive. This increased investment has a positive effect on the accumulation of both the tangible capital of the foreign firm in the home country and the technology capital of the foreign firm. Moreover, depending on the level of exposure and the size of the shock, the increased investment may also induce an increase in tangible capital of the foreign firm in the foreign country, due to the complementarity with technology capital. Therefore, the higher the FDI exposure is, the larger the stock price correlations are. Key to this channel is the presence of technology capital, without which the effect on the foreign capital of the foreign firm is absent. We will discuss this point further at the end of the section.

Impulse responses from our model can be used to understand the model mechanisms that produce these patterns. Here, for expositional clarity, we present impulse responses from a model where the exogenous TFP process is assumed to be uncorrelated, i.e. $corr(\varepsilon_{1t}, \varepsilon_{2t}) = 0$.[9] Figure 5 presents impulse responses to a persistent, one standard deviation increase in the TFP of the home country Z_1. The solid lines represent variables before the increase in FDI and the dotted lines the variables after the increase in FDI. The initial impact of the TFP increase is to increase production in the home country, i.e. both Y_1^1 and Y_1^2. The effect is exactly symmetric on the two plants, which implies a symmetric increase in labor demand by the two plants. Because labor is inelastic at the country level, wages in the home country increase and there is no re-allocation of labor across the two plants on impact. The effect is to increase the current cash flow for firm h, i.e. the right hand side of the firm financing constraint

$$D_t^h + X_t^h = Y_{1t}^h - W_{1t}N_{1t}^h + Y_{2t}^h - W_{2t}N_{2t}^h. \tag{23}$$

The effect is larger for the home firm, since most of its production and cash flow comes from the home plant and smaller for the foreign firm since its home plant is small relative to its plant in the foreign country. Importantly, this asymmetry in the size of the cash flow effect on the two firms becomes smaller as FDI increases.

We next discuss how this cash flow change feeds into the responses of investment and dividends. Firm investment responds for two reasons: a first direct effect is due to the TFP shock persistence, which implies higher expected TFP for the corresponding plants and increases the return to investment. The second effect is a smoothing motive that comes from the household side, through the stochastic discount factors of the two firms, which by construction coincide with the stochastic discount factors of the households that own the firms. In order to provide some consumption smoothing for its owners, the foreign firm will eventually substitute away from investment in the home country to increased and positive dividends for its owners in the foreign country. This means that dividends between the two firms may be negatively correlated, as the numerical results in table 2 indicate.

To further understand how these two channels that affect the stock price comovements operate, it is instructive to consider the two extreme cases of financial autarky and complete markets. Table 3 presents the numerical results from the same experiment as above, but now under these two financial market structures, and Figures 6 and 7 present impulse responses to a persistent, one standard deviation increase in Z_1, for financial autarky and complete markets respectively. The solid lines represent variables before the increase in FDI and the dotted lines the variables after the increase in FDI. First, we note that when markets are complete, stock prices comove more closely both before and after the change, but there is still a sizeable increase from 0.63 to 0.81 as a result of the increase in openness. At the other extreme, under financial autarky stock prices comove less overall, but the increase is still present and of similar magnitude going from 0.32 to 0.46. Looking at the impulse response functions, we observe that investment responds more symmetrically across firms when markets are complete, because of perfect insurance by households across the world, which implies that their marginal rate of substitution, i.e. the firm's discount factor, moves together in the two countries. In the absence of insurance possibilities (FA), because stochastic discount factors of the firms are not synchronized, stock price correlations are lower. Nevertheless, these numerical results suggest that the effect of increased expected returns to investment dominates, and therefore investment and hence stock market

[9] None of the discussions that follow hinge critically on this. Exogenous TFP correlation simply raises the levels of the correlations of stock prices, investment and dividends but does not change the fundamental workings of the model.

correlations are positive and increasing in FDI openness, irrespective of the comovement of dividends.

In more detail, under complete markets, households perfectly risk share and, as a result, there are contingent claims payments going from home households to the foreign households ensuring that consumptions, and marginal rates of substitution, move in tandem. The result is that both firms increase investment and decrease dividends. This works from a household risk-sharing perspective because the higher wage income of home households is spread to foreign households through contingent claim payments. The end result is a positive correlation of investment and stock prices and a positive correlation of dividends too. These correlations are stronger with higher FDI levels, because the foreign firm's investment response is stronger and closer to the home firm's response. At the other extreme of financial autarky, investment and stock prices are still positively correlated, albeit less so, but dividends are negatively correlated. The reason for this is the total absence of household risk sharing through financial assets, which implies that their marginal rates of substitution, i.e. firm discount factors, are asynchronous. The foreign firm is still exposed to the home TFP shock and still increases investment to take advantage of higher returns. But it increases investment by *less* to provide consumption smoothing for its stock owners. This allows the foreign firm to increase dividends immediately and smooth the consumption benefits of the productivity increase. Thus, dividends by the foreign firm increase at the same time as dividends decrease for the US firm, generating a negative correlation of dividends. Furthermore, with more FDI exposure, the foreign firm is affected more by the home TFP shock and increases both its investment and dividends more strongly. This makes dividend correlations even more negative.

An alternative way to look at stock prices is by reference to the usual pricing equation relating the stock price to the expected discounted sum of dividends, where the firm's discount factor reflects shareholders' marginal rate of substitutions. Although it is tempting to infer stock price comovements by looking at the correlation of dividends and the correlation of stochastic discount factors this can be misleading. Both the covariance of the marginal rate of substitution with foreign firm dividends and the serial correlation of both these variables would need to be taken into account, and this makes it harder to obtain a simple intuitive explanation using this approach. It is nevertheless interesting to highlight the behavior of dividends in our model, as this is an observable that is often used to analyze the sources of equity price comovements (see, for example, Jorda, Schularick, Taylor and Ward, 2019). In our model dividends are *positively correlated* when markets are complete and their correlation increases as FDI increases. In contrast, if markets are sufficiently incomplete, dividends can be *negatively correlated* and become even more so as FDI increases. Despite this, stock prices are still positively correlated and that correlation increases with FDI regardless of the financial market structure or the sign of the dividend correlation.

In summary, a production based asset pricing model ties stock prices to investment and, with more FDI exposure, multinationals respond positively and by more to foreign shocks. This implies an increase in stock market correlations. Looking at dividend correlations can be misleading as a means of inferring stock price comovements. If anything, the level and change in dividend correlations is more relevant for the level of financial market completeness, and could potentially be used as a test of market completeness.[10]

[10] Marcet and Scott (2009) use a similar idea to test for market completeness in government debt markets by looking at contradictory implications of complete and incomplete markets models for debt persistence and for the covariance of debt and deficit.

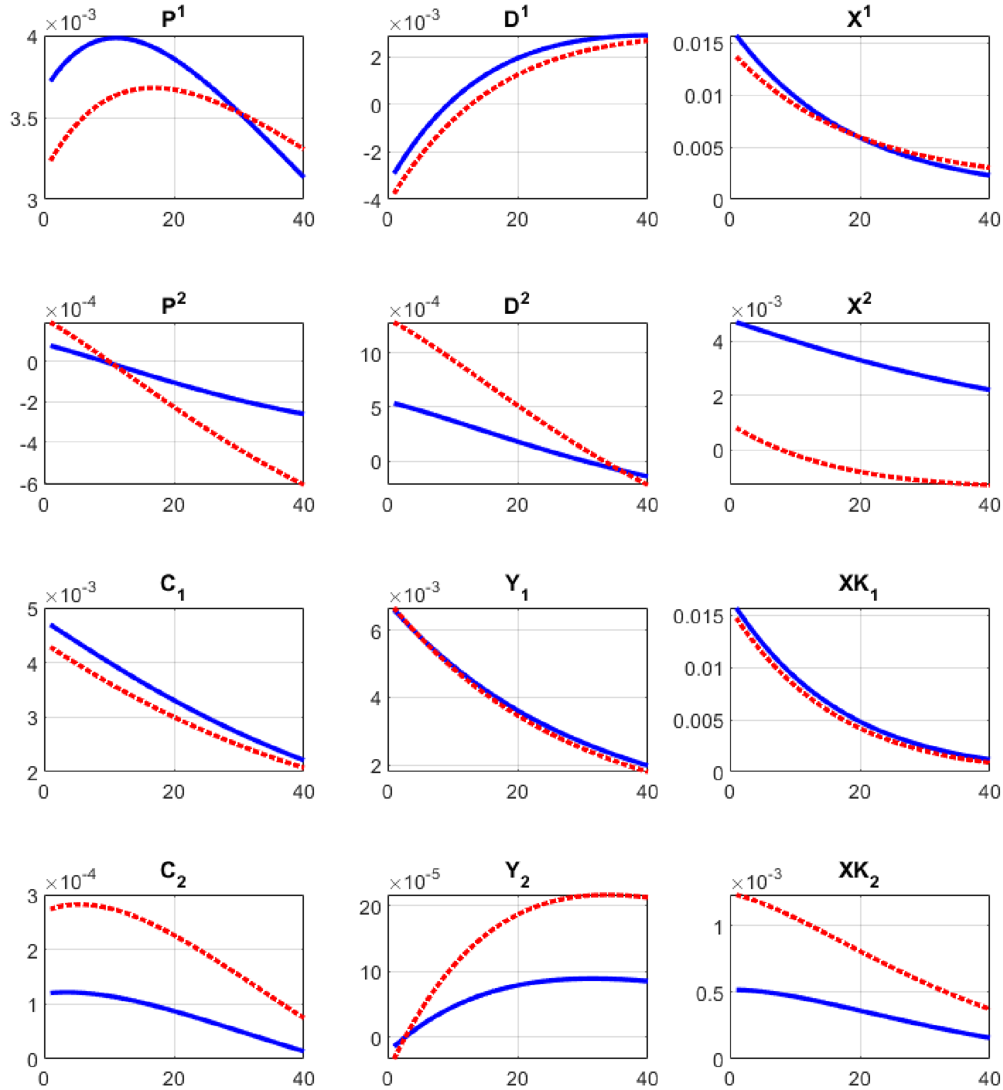

Figure 6: Impulse response functions, under FA. Shock to TFP of country 1. Blue solid line generated using σ_{lo}, red dotted line generated using σ_{hi}.

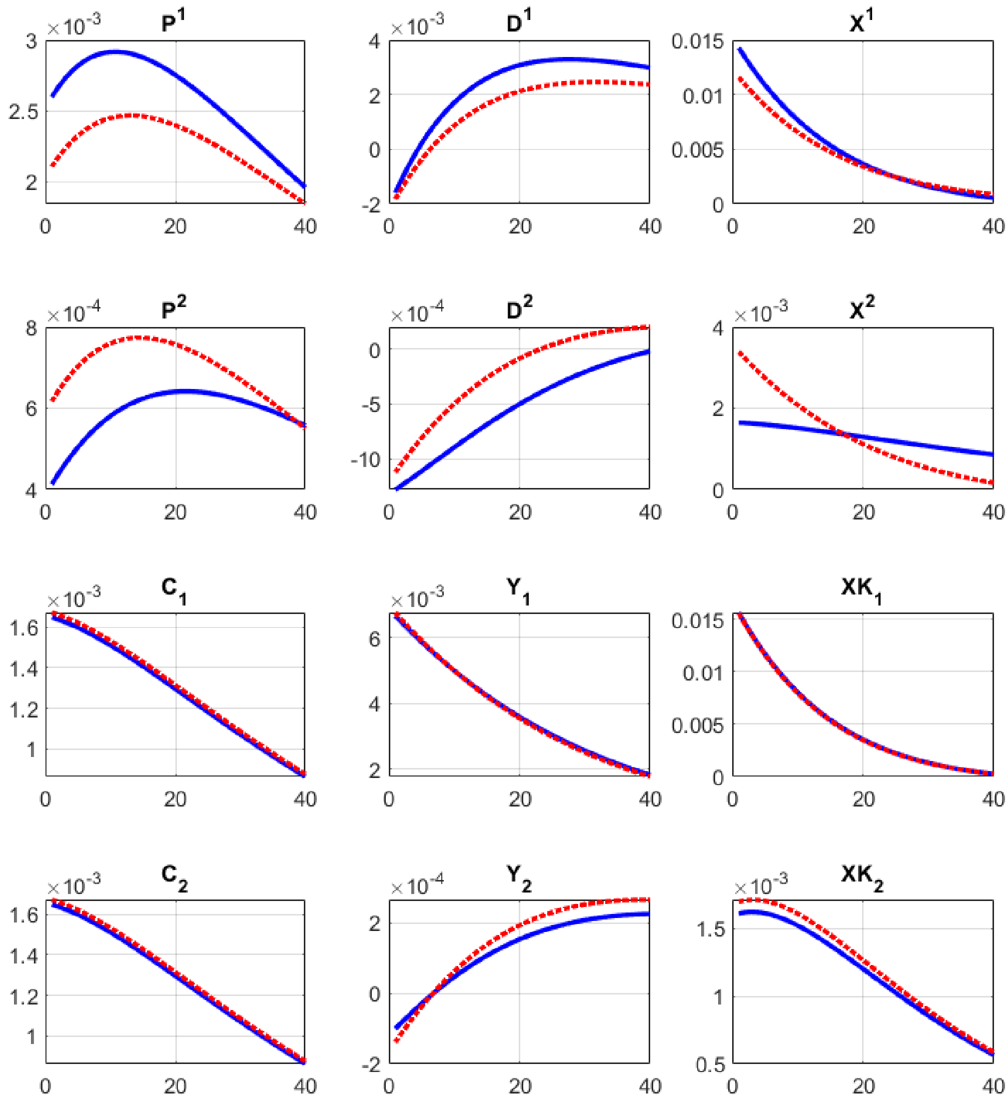

Figure 7: Impulse response functions, under CM. Shock to TFP of country 1. Blue solid line generated using σ_{lo}, red dotted line generated using σ_{hi}.

	Financial Autarky		Complete Markets	
	FDI_{low}	FDI_{high}	FDI_{low}	FDI_{high}
$corr(P^1, P^2)$	0.321	0.462	0.628	0.815
$corr(X^1, X^2)$	0.321	0.461	0.627	0.814
$corr(K^1, K^2)$	0.321	0.460	0.635	0.818
$corr(D^1, D^2)$	-0.218	-0.565	0.820	0.931
$corr(C_1, C_2)$	0.317	0.413	1.000	1.000
$corr(GDP_1, GDP_2)$	0.249	0.248	0.247	0.247
$corr\,(X_{K,1}, X_{K,2})$	0.327	0.422	0.514	0.522

Table 3: Correlations of stock prices, total firm investment, total firm capital, firm dividends, country consumptions, GDP and country tangible capital investment, under FA and CM.

We close with a discussion of the importance of technology capital. First we note that, contrary to the standard international business cycles model, e.g. as in Backus, Kehoe and Kydland (1992, 1995), the presence of technology capital implies a positive cross-country correlation of investment. In addition, our model also predicts an increase in this cross-country correlation of investment in response to increased FDI, which is consistent with the findings of Menno (2017) and Jorda, Schularick, Taylor and Ward (2019). Menno (2017) finds a significant effect of FDI increases on the synchronization of investment across countries, but little evidence of an effect on the synchronization of GDP. This is consistent with the results of our experiment. Jorda, Schularick, Taylor and Ward (2019) observe an increase in both GDP and investment correlations during this period, with the investment correlation increase being slightly larger than the one of GDP and both much less significant than the increase in equity price correlation. Our model provides a mechanism that can help understand these movements. GDP correlations in our model simply reflect the exogenous correlation of TFP shocks because we have assumed inelastic labor supply. The implication is that neither changes in FDI nor the market structure affect these correlations, and our model cannot say much on this front. However, our model does generate a modest increase in the correlations of measured (i.e. tangible) investment, $X_{K,i} = X^1_{K,i} + X^2_{K,i}$, and a larger increase in stock price correlations. This apparent inconsistency between a small increase in measured investment correlation and a large increase in stock price correlations is explained in our model by the presence of unmeasured technology capital investment.

5. Portfolio Diversification

A point often discussed in the literature relates to the importance of international asset portfolios being more diversified. Here, we allow for diversified portfolios and explore how much of the stock market correlation increase could be attributed to increased diversification.

If households have a full set of contingent claims available for trade (i.e. CM), the introduction of portfolio diversification is moot. Firm decisions on dividends and investment are decoupled from cross-country risk sharing considerations. Marginal rates of substitution are equalized across countries state-by-state and the portfolio composition is indeterminate and irrelevant for stock price comovement. Note that, as discussed in the previous section, FDI still plays a significant role, since it directly affects the synchronization of investment across firms. This is an important first takeaway, namely that FDI can matter over and above any risk sharing role that it might play and that distinguishes FDI from household portfolio diversification.

Taking the other extreme, where households cannot trade any financial assets across countries (i.e.

FA), we now introduce cross border holdings of stocks. Let Θ^h_{it+1} be the total shares of firm h held by residents of country i and define $\theta^h_{it+1} = \Theta^h_{it+1}/\upsilon_i$ to be the shares of a household in country i. Market clearing requires that

$$\Theta^h_{1t+1} + \Theta^h_{2t+1} = 1 \text{ for } h = 1, 2. \tag{24}$$

Household's i budget constraint is now adjusted to

$$c_{it} + P^1_t \theta^1_{it+1} + P^2_t \theta^2_{it+1} = W_{it} n_{it} + \left(D^1_t + P^1_t\right) \theta^1_{it} + \left(D^2_t + P^2_t\right) \theta^2_{it}. \tag{25}$$

Solving the model with a portfolio choice for households is beyond the scope of our paper, but we can get a sense of the effects of diversification by making a simplifying assumption: households can only trade shares of their home firm. This also means that households' share holdings of the foreign firm cannot be traded and, hence, shares are traded only within a country. Let λ^h_i be the total number of shares of firm j held by households in country i. That is, $\lambda^2_1 \equiv \Theta^2_{1t+1} = \upsilon_1 \theta^2_{1t+1}$and $\lambda^1_2 \equiv \Theta^1_{2t+1} = \upsilon_2 \theta^1_{2t+1}$. Stock market clearing is now

$$\upsilon_i \theta^i_{it} = \lambda^i_i,\ i = 1, 2, \tag{26}$$

with

$$\sum_i \lambda^j_i = 1,\ \ j = 1, 2. \tag{27}$$

In this case, the home firm's market price depends on the marginal rate of substitution of home households only, and the equilibrium budget constraint is

$$\begin{aligned} c_{it} + P^i_t \frac{\left(1-\lambda^i_j\right)}{\upsilon_i} + P^j_t \frac{\lambda^j_i}{\upsilon_j} &= W_{it} n_{it} + \left(D^i_t + P^i_t\right) \frac{\left(1-\lambda^i_j\right)}{\upsilon_i} + \left(D^j_t + P^j_t\right) \frac{\lambda^j_i}{\upsilon_j} \Rightarrow \\ c_{it} &= W_{it} n_{it} + D^i_t \frac{\left(1-\lambda^i_j\right)}{\upsilon_i} + D^j_t \frac{\lambda^j_i}{\upsilon_j}, \quad j \neq i. \end{aligned} \tag{28}$$

Note that marginal rates of substitution are now not equalized state-by-state, which implies no unanimity (in general) on the firm objective. We follow a common approach in the literature of defining the firm objective using the home country marginal rates of substitution of the two shareholders.

Table 4 reports the change in correlations of our benchmark model to different levels of portfolio diversifications, from a perfect home bias to perfect diversification. The main result arising from this exercise is that increases in portfolio diversification (i.e. increases in $\lambda^j_i = \lambda^i_j$) have a negative effect on stock price correlations. When we allow the consumer to hold foreign assets, consumption correlations decrease and stochastic discount factors of the firms are then less synchronized. Despite the increase of the return to investment due to the TFP shock, price correlations are then lower. Nevertheless, when we consider a level of portfolio diversification close to the one observed in the data (10%) we find that the level of the correlations is only marginally affected.

6. Additional empirical evidence

We aim to uncover a relationship between the correlations of international stock markets and FDI. In particular we examine the impact of FDI position between two countries on the correlation of the stock market returns of the two countries (i.e. on the correlation of the growth rate of stock market prices),

$\lambda_i^j = \lambda_j^i$	0.0	0.1	0.5
$corr(P^1, P^2)$	0.382	0.361	0.240
$corr(X^1, X^2)$	0.383	0.362	0.242
$corr(K^1, K^2)$	0.368	0.245	0.208
$corr(D^1, D^2)$	0.139	0.027	-0.446
$corr(C_1, C_2)$	0.365	0.359	0.280
$corr(GDP_1, GDP_2)$	0.250	0.250	0.280
$corr\ (X_{K,1}, X_{K,2})$	0.372	0.357	0.273

Table 4: Correlations of stock prices, total firm investment, total firm capital, firm dividends, country consumptions, GDP and country tangible capital investment, with portfolio diversification.

controlling for a set of relevant macroeconomic variables. Our data set consists of six countries, as listed in Section 2 (US, Canada, Japan, UK, France and Germany), i.e. we have $N = 15$ country pairs over $T = 24$ years, up to 2012, due to the restrictions that relate to how FDI positions are calculated. In our specifications, the dependent variable is stock market correlations, as calculated in Section 2 based on the MSCI indices and the explanatory variable is the relative FDI position measure RF. We also allow for a variety of other controls, namely a measure of bilateral trade, as well correlations of industrial production, interest rates and inflation rates, defined in the same way as the correlations of the MSCI indices.[11] Of these controls, perhaps the most interesting one is trade, since it is often thought that the amount of trade openness between two countries has implications for business cycle and financial markets comovements. For this reason, and as a first check, we juxtapose our bilateral FDI data with the corresponding bilateral trade data for the six big economies of interest. These series are shown in Figure 8, where we can see that on one hand FDI seems to be increasing in the period of interest, while on the other hand, trade appears to be relatively stable or in some cases decreasing over time.

Regarding our estimations, we note that macro time series panels such as the one we work with are plagued by a variety of problems, such as non-stationarities, pervasive endogeneity, as well as cross-sectional dependence (typically absent in standard micro, longitudinal panels). Moreover, as such panels are typically of small size, i.e. the number of groups N is relatively small and often of the same order or magnitude as the number of time periods T, estimation is potentially subject to small-sample bias. All these are issues that we account for carefully here. On the positive side, because the number of time periods for time series panels is longer than micro panels, it is possible to account for possible slope heterogeneity. Indeed, we tested our data for the presence of (i) panel unit roots (using the tests of Levin, Li and Chu, 2002; Im, Pesaran and Shin, 2007), (ii) cross-sectional dependence (using the tests of Pesaran, 2004; Friedman, 1937; Frees, 1995) and (iii) serial correlation in panel data (using the test of Woolridge, 2002). We find strong evidence of the presence of both cross sectional dependence and serial correlation. Also, we cannot confidently reject the hypothesis of the presence of unit roots in some of the variables, such as our FDI measure and the trade measure, even when a deterministic linear trend is removed from those.

Given these results and together with the fact that we are essentially after estimating a long run relationship between stock market correlations and FDI, we resort to estimation methods that are

[11] For our trade measure we use the database of the Center for International Data from UC Davies (for data up to 2000), and Com Trade (for data post 2000). Trade is calculated relative to the sum of GDPs of the two countries, similarly to RF. The source for the remaining controls is OECD.

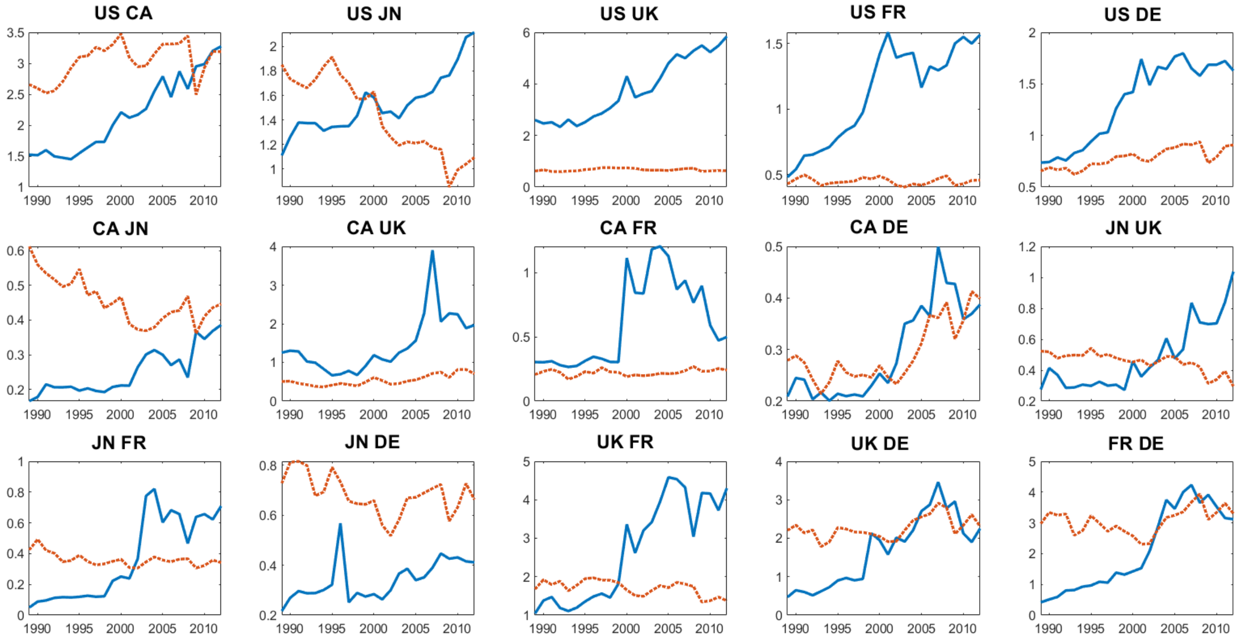

Figure 8: Trade (dotted line) and FDI positions (solid line), between United States (US), Canada (CA), Japan (JN), United Kingdom (UK), France (FR), Germany (DE). Data in annual frequency, source: *OECD* and *ComTrade.*

more suitable for panel time series. Such methods can account for some of these issues and can provide reliable estimates. Under the presence of cross-sectional dependence, endogeneity or non-stationarity standard micro panel methods typically give inconsistent and/or biased estimates, we therefore do not report such estimates extensively. We resort to do two sets of estimations, by assuming that the panel is first static and second it is dynamic. The tables in the Appendix show the estimation results where the dependent variable is the measure of stock market correlation and the explanatory variables are the measures of relative FDI and other controls, for (a) static panels, using fixed effects estimation (assuming homogeneous slopes), and mean group estimates (assuming heterogeneous slopes) and (b) dynamic panels, based on the autoregressive distributed lag model (ARDL), using pooled mean group (PMG) and mean group (MG) estimates (for these cases, we only report one of the two estimates, namely the one selected by a Hausman test). For details on the ARDL and CS-ARDL models and proposed estimators, see Chudik, Mohaddes, Pesaran and Raissi (2016). The results from these tables generally support the importance of FDI positions as a determinant for cross-country stock market comovements, and the effects are especially strong under the ARDL specification, which we believe is more appropriate for the panel we work with.

7. Closing comments

Cross-country stock market correlations have seen a sharp rise in the past 30 years. This is a well documented fact, but not much is known about the factors that have contributed to this increase. In this paper we establish a relationship between the rise in cross-country stock market correlations and the increase in FDI positions in the last thirty years, both empirically and theoretically. The increase in stock marker correlations observed in the data very clearly coincides with a sharp increase in FDI positions among big developed economies that took place between mid 1990s to mid 2000s. This positive relationship between stock market correlations and FDI is still present even when controlling for other potential determining factors such as trade, the business cycle, monetary policy, etc. Our theoretical framework is rich enough to provide a meaningful calibrated asset pricing model of the US economy versus the rest of the world, yet parsimonious enough to be able to disentangle the channels that matter for the comovements of the two stock markets. There are two key elements of the model that are important for establishing the link between FDI and stock markets: first the multinational firms, that engage in foreign direct investment, and second the presence of intangible (technology) capital in the production functions of the firms. With these two in place, we show that the comovement of investment drives to a large extent the comovement in stock prices. In our benchmark calibration, FDI was found to generate approximately one third of the observed rise in stock market comovement. We have also shown that the level of financial market completeness can be an important determinant of the level of stock price correlations, indicating that an improvement in asset market trade opportunities could potentially explain some of the additional unexplained increase. However, we have argued that, at least in the context of our model, increased portfolio diversification alone cannot help in explaining stock market correlations increases.

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A. Derivation of stock market prices

The problem of the firm is

$$\max_{N_{it}^h,\ K_{i,t+1}^h, M_{t+1}^h} \quad \mathbb{E}_0 \sum_{t=0}^{\infty} \Psi_{0,t}^h \Big\{ A_1 Z_{1t} \sigma_1^h (\upsilon_1 M_t^h)^{\alpha_M} (K_{1t}^h)^{\alpha_K} (N_{1t}^h)^{\alpha_N} + A_2 Z_{2t} \sigma_2^h (\upsilon_2 M_t^h)^{\alpha_M} (K_{2t}^h)^{\alpha_K} (N_{2t}^h)^{\alpha_N}$$
$$-W_{1t} N_{1t}^h - W_{2t} N_{2t}^h - X_{K,1t}^h - X_{K,2t}^h - X_{M,t}^h$$
$$+q_{1t}^h \left[-K_{1t+1}^h + (1-\delta_K) K_{1t}^h + X_{K,1t}^h - \Phi\left(\frac{X_{1t}^h}{K_{1t}^h}\right) K_{1t}^h \right]$$
$$+q_{2t}^h \left[-K_{2t+1}^h + (1-\delta_K) K_{2t}^h + X_{K,2t}^h - \Phi\left(\frac{X_{2t}^h}{K_{2t}^h}\right) K_{2t}^h \right]$$
$$+q_{Mt}^h \left[-M_{t+1}^h + (1-\delta_M) M_t^h + X_{M,t}^h - \Xi\left(\frac{X_t^h}{M_t^h}\right) M_t^h \right] \Big\}. \tag{29}$$

The FOC with respect to X_{1t}^h is:

$$q_{1t}^h = \frac{1}{1-\Phi'\left(X_{1t}^h / K_{1t}^h\right)}, \tag{30}$$

and the FOCs with respect to $K_{i,t+1}^h$ is

$$q_{1t}^h = \mathbb{E}_t \left\{ \Psi_{t,t+1}^h \left(\alpha_K \frac{Y_{i,t+1}^h}{K_{i,t+1}^h} + q_{1t+1}^h \left[(1-\delta_K) + \Phi'\left(X_{it+1}^h / K_{it+1}^h\right)\left(X_{it+1}^h / K_{it+1}^h\right) - \Phi\left(X_{it+1}^h / K_{it+1}^h\right) \right] \right) \right\}.$$

Finally, we have

$$\begin{aligned} & \frac{1}{1-\Phi'\left(X_{it}^h / K_{it}^h\right)} \\ = \; & \mathbb{E}_t \left\{ \Psi_{t,t+1}^h \left(\alpha_K \frac{Y_{i,t+1}^h}{K_{i,t+1}^h} + \frac{1}{1-\Phi'\left(X_{it+1}^h / K_{it+1}^h\right)} \left[(1-\delta_K + \Phi'\left(\frac{X_{it+1}^h}{K_{it+1}^h}\right)\left(\frac{X_{it+1}^h}{K_{it+1}^h}\right) - \Phi\left(\frac{X_{it+1}^h}{K_{it+1}^h}\right) \right] \right) \right\}. \end{aligned} \tag{31}$$

Similarly, with the FOC with respect to M_t^h is

$$\begin{aligned} & \frac{1}{1-\Phi'\left(X_{M.t}^h / M_t^h\right)} \\ = \; & \mathbb{E}_t \left\{ \Psi_{t,t+1}^h \left(\alpha_M \frac{Y_{1t+1}^h + Y_{2t+1}^h}{M_{t+1}^h} \right.\right. \end{aligned} \tag{32}$$

$$\left.\left. + \frac{1}{1-\Phi'\left(X_{M.t+1}^h / M_{t+1}^h\right)} \left[(1-\delta_M) + \Phi'\left(\frac{X_{M,t+1}^h}{M_{t+1}^h}\right)\left(\frac{X_{M,t+1}^h}{M_{t+1}^h}\right) - \Phi\left(\frac{X_{M,t+1}^h}{M_{t+1}^h}\right) \right] \right) \right\}. \tag{33}$$

In order to show the expression linking prices and capitals, first we take (31) and (32) and rewrite them by multiplying with K_{t+1} and M_{t+1}, then using their capital accumulation equation, to get

$$\frac{K_{i,t+1}^h}{1-\Phi'\left(X_{it}^h / K_{it}^h\right)} = \mathbb{E}_t \left\{ \Psi_{t,t+1}^h \left(\alpha_K Y_{i,t+1}^h - X_{it+1}^h + \frac{K_{i,t+2}^h}{1-\Phi'\left(X_{it+1}^h / K_{it+1}^h\right)} \right) \right\}.$$

Adding the three capitals, we get

$$\frac{K_{1,t+1}^h}{1-\Phi'\left(X_{1t}^h/K_{1t}^h\right)}+\frac{K_{2,t+1}^h}{1-\Phi'\left(X_{2t}^h/K_{2t}^h\right)}+\frac{M_{t+1}^h}{1-\Phi'\left(X_{M,t}^h/M_t^h\right)}$$

$$= \mathbb{E}_t\left\{\Psi_{t,t+1}^h\left[D_{t+1}^h+\frac{K_{1,t+2}^h}{1-\Phi'\left(X_{1t+1}^h/K_{1t+1}^h\right)}+\frac{K_{2,t+2}^h}{1-\Phi'\left(X_{2t+1}^h/K_{2t+1}^h\right)}+\frac{M_{t+2}^h}{1-\Phi'\left(M_{t+1}^h/K_{1t+1}^h\right)}\right]\right\}$$

and letting the sum of capitals be

$$\mathcal{K}_{t+1}^h \equiv \frac{K_{1,t+1}^h}{1-\Phi'\left(X_{1t}^h/K_{1t}^h\right)}+\frac{K_{2,t+1}^h}{1-\Phi'\left(X_{2t}^h/K_{2t}^h\right)}+\frac{M_{t+1}^h}{1-\Phi'\left(X_{M,t}^h/M_t^h\right)} \tag{34}$$

we have that

$$\mathcal{K}_{t+1}^h = \mathbb{E}_t\{\Psi_{ht,t+1}\left(D_{t+1}^h+\mathcal{K}_{t+2}^h\right)\}. \tag{35}$$

Using law of iterated expectations and substituting forward (using the transversality condition) we have that

$$\mathcal{K}_{t+1}^h = \mathbb{E}_t\sum_{j=1}^{\infty}\Psi_{ht,t+j}D_{t+j}^h. \tag{36}$$

Finally, from the Euler equation of the household in country h we have the asset pricing equation

$$P_t^h = \mathbb{E}_t\left[\Psi_{ht,t+1}\left(D_{t+1}^h+P_{t+1}^h\right)\right], \tag{37}$$

which by iterating forward gives

$$P_t^h = \mathbb{E}_t\sum_{j=1}^{\infty}\Psi_{ht,t+j}D_{t+j}^h. \tag{38}$$

From this and (34) we conclude that

$$P_t^h = \frac{K_{1,t+1}^h}{1-\Phi'\left(X_{1t}^h/K_{1t}^h\right)}+\frac{K_{2,t+1}^h}{1-\Phi'\left(X_{2t}^h/K_{2t}^h\right)}+\frac{M_{t+1}^h}{1-\Phi'\left(X_{M,t}^h/M_t^h\right)}. \tag{39}$$

B. Tables of empirical results

STATIC PANEL MODELS

	(a) Homogenous slopes			(b) Heterogeneous slopes						
	FE	FE	FE	MG	MG	MG	MG	MG	MG	AMG
$\hat{\beta}_{fdi}$	0.2589***	0.2555***	0.2343***	0.3911***	0.3312***	0.3109***	0.1078**	0.1025**	0.1182**	0.1401**
	(0.0544)	(0.0521)	(0.0516)	(0.0526)	(0.0531)	(0.0538)	(0.0467)	(0.0453)	(0.0488)	(0.0492)
$\hat{\beta}_{trade}$		0.1768	0.1520		0.1782*	0.1389		0.1631*	0.1300	0.0040
		(0.1431)	(0.1479)		(0.1053)	(0.0949)		(0.0986)	(0.0800)	(0.0797)
$trend$							0.0166***	0.0171***	0.0144***	-0.0034
							(0.0029)	(0.0029)	(0.0032)	(0.0034)
$\hat{\beta}_{ip}$			0.0267			0.0321*			0.0391	-0.0051
$\hat{\beta}_{\pi}$			0.0895			0.1137**			0.0997	0.0366
$\hat{\beta}_{ir}$			0.0322			0.0189			0.0231	0.0213*
$N \times T$	360	360	360	360	360	360	360	360	360	360
										26.7%

Legend: The econometric specification is given by $y_{it}= c_i+\beta_i' x_{it}+u_{it}$, where y_{it} is the correlation of the difference of logs of stock market prices for country pair i at t, and $x_{i,t}$ contains the explanatory variables. The symbols *, **, *** denote significant estimates at 1%, 5% and 10% level. Numbers in parentheses for (a) are robust standard errors, and standard errors for (b). The last column shows estimates based on the agumented mean group estimator, which allows for group-specific trends. The number in the bottom right corner indicates the share of group-specific trends that are significant at 5% level (here 4 trends).

DYNAMIC PANEL MODELS WITH MG/PMG

	On lag					**Two lags**				
	(a) **ARDL(1,1)**			(b) **CS-ARDL(1,1)**		(a) **ARDL(2,2)**			(b) **CS-ARDL(2,2)**	
	MG	PMG	MG	PMG	PMG	MG	MG	PMG	PMG	PMG
$\hat{\theta}_{fdi}$	0.4172***	0.2920***	0.3462***	0.2119***	0.1847***	0.4558***	0.2891***	0.2885***	0.2372***	0.2044***
	(0.0498)	(0.0231)	(0.0755)	(0.0215)	(0.0221)	(0.0592)	(0.0846)	(0.0112)	(0.0129)	(0.0188)
$\hat{\theta}_{trade}$		0.0546	0.3188**		0.0799		0.3969**	0.1146**		0.0119
		(0.0924)	(0.1302)		(0.0895)		(0.1834)	(0.0465)		(0.0587)
$\hat{\theta}_{ip}$			-.0221					0.0652***		
			(0.0805)					(0.0150)		
$\hat{\theta}_{\pi}$			0.0874					-.2155***		
			(0.0751)					(0.0363)		
$\hat{\theta}_{ir}$			0.1165					0.1427***		
			(0.0912)					(0.0155)		
$\hat{\lambda}$	-.1689**	-.5442***	-.8001***	-.7981***	-.8700***	-.7944***	-.8478***	-.5269***	-.8862***	-.9038***
$N \times T$	345	345	345	345	345	330	330	330	330	330

Legend: The ARDL(p,q) specification is given by $y_{it}= c_i+\Sigma_{l=1}^{p}\varphi_{\iota l}y_{i,t-l}+\Sigma_{l=0}^{q}\beta'_{il}x_{i,t-l}+u_{it}$ or in EC form $\Delta y_{it}= \lambda_i\left(y_{it-1}-\theta'_i x_{it}\right) + \Sigma_{l=1}^{p-1}\varphi^*_{il}\Delta y_{i,t-l}+\Sigma_{l=0}^{q-1}\beta^{*\prime}_{il}\Delta x_{i,t-l}+\tilde{u}_{it}$, where y_{it} is the correlation of the difference of logs of stock market prices for country pair i at t, and $x_{i,t}$ contains the explanatory variables (measures of FDI and trade, and the correlations of difference logs of industrial production, inflation rate and the correlation of nominal interest rates). The symbols *, **, *** denote significant estimates at 1%, 5% and 10% level. Numbers in parenthesis are standard errors. We have performed MG and PMG estimationsand only report estimates selected by a Hausman test for testing that "H_0: difference in coefficients MG - PMG is not systematic". For ARDL-CS we do not include more controls than trade, because the sample reduces a lot.