Multinational Production, Risk Sharing, and Home Equity Bias*

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Abstract

We study the consequences of offshoring for international equity portfolios, risk sharing, and the international transmission of technology and government spending shocks. We show analytically that serving foreign markets by producing locally can substitute for international asset trade and terms of trade adjustment in delivering perfect risk sharing across countries: Offshore production implies that the consumption differential is tied to the real exchange rate even if the optimal equity portfolio is fully home-biased and the elasticity of substitution between domestic and foreign goods in consumption is different from one. Net foreign assets do not move in response to shocks. We investigate how the extent to which firms use source- versus host-country technology when producing abroad matters for the international transmission of shocks. A numerical illustration allows us to compare transparently the properties of our model to those of the alternative environment in which firms serve foreign markets by exporting.

Keywords: Home bias, international business cycles, multinational production, offshoring, risk sharing

JEL classification: F41, G11, G15

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1 Introduction

The years since the mid-1980s have been characterized by a large expansion in foreign direct investment (FDI) flows.[1] Serving foreign markets by means of local affiliates and fragmenting production along value chains that straddle multiple borders have become part of the modus operandi of most successful corporations. This raises interesting questions about the determination of the international portfolio choices of domestic and foreign savers, the properties of these portfolios, and how they interact with macroeconomic dynamics: If firms serve foreign markets by producing locally (rather than by producing domestically and then exporting their output), how does this affect the optimal portfolio of domestic and foreign equities that households should hold? What are the risk sharing properties of this portfolio? What is the extent to which households can diversify risk by holding portfolios that consist mostly of shares in domestic multinational companies (MNCs)? And what do offshore production and optimal portfolios imply for the transmission of shocks to international relative prices and macroeconomic aggregates?

We address these questions in a two-country, dynamic stochastic general equilibrium (DSGE) model in which firms serve foreign consumers by producing abroad, and households in each country hold portfolios of shares in both domestic and foreign firms.[2] The model is based on Ghironi, Lee, and Rebucci (2015—GLR below). Households consume, supply labor and hold equity shares. Asset markets are incomplete, as the number of assets that are traded by agents is smaller than the number of shocks. Firms are monopolistically competitive and generate profits, distributed to households as dividends, by producing and selling output domestically and abroad. Labor is the only factor of production, and our key departure from GLR is that, in order to serve the foreign market, home firms produce in the foreign country and employ foreign labor.[3] We assume that this overseas production is subject to a combination of domestic and foreign productivity shocks, capturing the idea

[1] This is true even accounting for the large oscillations at the beginning of the 2000s and in response to the global crisis of 2008-09, and for the slowdown in FDI growth since the Great Recession.

[2] Thus, we focus on the portfolio and macroeconomic implications of serving foreign markets through foreign affiliates rather than the consequences of production fragmentation with final output sale that takes place domestically. We leave this alternative scenario for future exploration.

[3] Relative to our paper, GLR represents the opposite extreme in which firms serve foreign markets exclusively by exporting.

that FDI transfers technology across borders, but also that production is subject to shocks that are specific to local technology.

We intentionally keep the model simple enough that it can be solved analytically using the technique developed by Devereux and Sutherland (2011) and Tille and van Wincoop (2010). This delivers a set of striking implications: The optimal portfolio implies that households hold zero equity in foreign firms, but this is sufficient to ensure replication of the complete markets outcome, with the consumption differential between countries tied to the real exchange rate in proportional fashion. The real exchange rate adjusts to cross-country differences in wages and productivities so as to deliver full risk sharing, and net foreign assets do not move in response to shocks.

Strikingly, multinational production causes the perfect risk sharing outcome to arise even if the elasticity of substitution between domestic and foreign goods in consumption is different from one. It is a well known result since Cole and Obstfeld (1991—CO below) that when goods are delivered to foreign consumers through traditional trade, if the consumption basket takes a Cobb-Douglas form, movements in the terms of trade yield the complete markets allocation in absence of any asset trade. In our model, there is no actual trade in goods because all consumption is produced locally. The real exchange rate fluctuates (i.e., consumption-based purchasing power parity—PPP—does not hold) because domestic and foreign consumption baskets incorporate different productivity contents across countries, and there is no trade in goods that would enforce the law of one price. In turn, these movements in the real exchange rate (or in relative labor costs across countries) ensure optimal risk sharing even if portfolios do not include any foreign equity, without any movement of net foreign assets from the steady state, and regardless of the value of the elasticity of substitution between domestic and foreign goods.

A numerical illustration of responses to productivity and government spending shocks allows us to compare transparently the implications of offshore production versus traditional trade, and to explore how the extent to which firms use source- versus host-country technology when producing abroad matters. In GLR, a positive technology shock implies an increase in domestic employment relative to foreign as familiar resource-shifting results in increased production in the country that has received the favorable shock and increased employment of its labor. With offshore production, the technology structure shapes the effect of the shock on relative employment: There is no differential in employment across countries if firms use only their own country's technology regardless of where they produce, otherwise domestic employment actually falls relative to foreign. In GLR, a relative increase in home labor effort is also needed for home households to make up for the loss of purchasing power implied by terms of trade depreciation. By contrast, we show that offshore production with exclusive use of host-country technology implies the largest increase in the purchasing power of home incomes, which allows home households to sustain any given level of consumption with lower labor effort. Wages mirror the dynamics of labor: In GLR, increased employment of home labor drives home wages above foreign; however, the largest increase in the wage differential happens with offshore production and exclusive use of host-country technology.

The paper is related to several literatures. It contributes to vast literatures on risk sharing and home equity bias in international portfolios by exploring the consequences of international production. The mechanisms that ensure risk sharing between domestic and foreign consumers are key to the properties of virtually every model in modern international macroeconomics, and to the "puzzles" that these models result in or resolve in relation to the empirical evidence. Benigno and Thoenissen (2008) and Corsetti, Dedola, and Leduc (2008) are representative examples of articles that explore the consequences of risk sharing or lack thereof for the propagation of international macroeconomic fluctuations. We contribute to this literature by showing that international production implies a CO-type result even in absence of goods trade, regardless of the value of substitutability between domestic and foreign goods. Our results provide transparent benchmarks for how the mechanism we focus on would impact the properties and quantitative performance of richer models that may embed it in the future.

As for home equity bias, empirical research produced conflicting conclusions on the consequences of MNCs for international portfolio diversification, creating a long-standing puzzle on whether investing in shares of MNCs provides investors with international diversification.[4]

[4] For instance, Errunza, Hogan, and Hung (1999) find that home investors can gain international diversification benefits by investing in home-based MNCs, but Rowland and Tesar (2004) conclude that investing in home-based MNCs generally does not produce substantial international diversification benefits whereas adding international stock market indices to a domestic portfolio does generate such benefits.

To the best of our knowledge, the extent to which MNCs can result in portfolios that are *optimally* skewed toward domestic equity has not been explored theoretically. We contribute on this front by obtaining results in a transparent, canonical setup that can provide guidance for future empirical investigations.

Last but not least, our work is related to a fast-growing literature on MNCs, portfolios, and asset prices at the intersection of international trade and international macroeconomics. Examples include Fillat and Garetto (2015), Fillat, Garetto, and Oldenski (2015), and Ramondo and Rappoport (2010). These papers explore the implications of multinational activity for asset prices (or returns) and risk sharing in models that incorporate endogenous decisions by firms on whether to engage in multinational production.[5] Ramondo and Rappoport (2010) is perhaps the paper that is closest to ours in terms of focus: Ramondo and Rappoport (2010) show that endogenous location decisions in the presence of costly market entry by heterogenous firms affect the extent to which households accomplish risk diversification even in an environment of complete asset markets. We abstract from the endogeneity of FDI decisions, taking overseas production as a given, and we focus on an extreme case in which all firms only serve the foreign market by producing abroad (in which case, as in Ramondo and Rappoport (2010), there generally is a transfer of technology). Our contribution consists in showing transparently that international production can "complete" the international asset market, and it can do so even if the optimal portfolio consists entirely of shares in domestic MNCs.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 discusses useful model properties and key analytical results. Section 4 substantiates the results and intuitions of Section 3 by presenting impulse responses to shocks and comparing them to those generated by the model in GLR. Section 5 concludes. A Technical Appendix contains additional details and proofs.

[5] Helpman, Melitz, and Yeaple (2004) is the benchmark reference in the trade literature on models of endogenous export versus FDI decisions. Contessi (2015) extends their model to a DSGE environment. Zlate (2016) develops a DSGE model in which offshoring happens to take advantage of lower labor costs, with output then exported from the host to the source country.

2 Model

This section outlines the model setup of households, governments, and firms.

2.1 Households and Governments

There are two countries: Home and Foreign. Each country is populated by infinitely lived, atomistic households. The world population equals the continuum $[0, 1]$. Home and Foreign households comprise the intervals $[0, a)$ and $[a, 1]$, respectively.

The representative Home household maximizes an expected intertemporal utility function that depends on consumption, C_t, and labor, L_t:

$$E_t \sum_{s=t}^{\infty} \beta^{s-t}(\frac{C_s^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \chi \frac{L_s^{1+\frac{1}{\varphi}}}{1+\frac{1}{\varphi}}),$$

where the discount factor β is $1 > \beta > 0$, the elasticity of intertemporal substitution is $\sigma > 0$, the Frisch elasticity of labor is $\varphi > 0$, and $\chi > 0$. The labor market is competitive and labor is immobile between countries. The representative Foreign household maximizes a similar utility function, with Foreign consumption and labor effort denoted by C_t^* and L_t^*.

The Home household's consumption basket, C_t, consists of bundles (or sub-baskets) of goods produced by Home and Foreign firms, denoted by C_{Ht} and C_{Ft}, respectively. These are aggregated in constant-elasticity of substitution (CES), Armington form:

$$C_t = [a^{\frac{1}{\omega}} C_{Ht}^{\frac{\omega-1}{\omega}} + (1-a)^{\frac{1}{\omega}} C_{Ft}^{\frac{\omega-1}{\omega}}]^{\frac{\omega}{\omega-1}},$$

where $\omega > 0$ denotes the elasticity of substitution between bundles of goods produced by Home and Foreign firms. As described in more detail in Section 2.2, the consumption sub-baskets C_{Ht} and C_{Ft} represent the Home household's consumption of goods produced by Home and Foreign firms in the *home* country. The bundles C_{Ht} and C_{Ft} aggregate consumption of individual, differentiated products in Dixit-Stiglitz CES fashion:

$$C_{Ht} = [(\frac{1}{a})^{\frac{1}{\theta}} \int_o^a c_t(z)^{\frac{\theta-1}{\theta}} dz]^{\frac{\theta}{\theta-1}} \text{ and } C_{Ft} = [(\frac{1}{1-a})^{\frac{1}{\theta}} \int_a^1 c_t(z^*)^{\frac{\theta-1}{\theta}} dz^*]^{\frac{\theta}{\theta-1}},$$

where Home firms are identified by z, Foreign firms are identified by z^*, and $\theta > 1$ is the elasticity of substitution.

The price indices follow from the above consumption preferences. The Home price index is:

$$P_t = [aP_{Ht}^{1-\omega} + (1-a)P_{Ft}^{1-\omega}]^{\frac{1}{1-\omega}}.$$

P_{Ht} and P_{Ft} are the price indices for the sub-baskets of goods produced in Home by Home and Foreign firms, respectively:

$$P_{Ht} = [\tfrac{1}{a}\textstyle\int_o^a p_t(z)^{1-\theta}dz]^{\frac{1}{1-\theta}} \text{ and } P_{Ft} = [\tfrac{1}{1-a}\textstyle\int_a^1 p_t(z^*)^{1-\theta}dz^*]^{\frac{1}{1-\theta}},$$

where $p_t(z)$ and $p_t(z^*)$ are the prices of individual goods.[6] The Foreign price index, P_t^*, is similarly a function of the price of the bundle of goods produced in the Foreign country by Home firms, P_{Ht}^*, and the price of the bundle of goods produced in the Foreign country by Foreign firms, P_{Ft}^*:

$$P_t^* = [aP_{Ht}^{*1-\omega} + (1-a)P_{Ft}^{*1-\omega}]^{\frac{1}{1-\omega}}.$$

The government consumes the same consumption basket as the households. Letting G_t be per capita government spending and anticipating symmetry of optimal behavior across households, $Y_t^d \equiv a(C_t+G_t)$ is the total demand for the Home country's consumption basket by all households and the government. The demand for Home firm z's output by all households and the government in the Home country is $(\frac{p_t(z)}{P_{Ht}})^{-\theta}(\frac{P_{Ht}}{P_t})^{-\omega}a(C_t+G_t)$. Government spending is exogenous and wasteful. The government's budget is balanced, and spending equals a lump-sum tax on household income.

In addition to supplying labor and consuming, Home households hold shares in Home and Foreign firms. Aggregate per capita holdings of Home and Foreign firms at the beginning of period $t+1$ are denoted by x_{t+1} and x_{t+1}^*, respectively. Similarly, Foreign households' aggregate per capita holdings of shares in Home and Foreign firms are denoted by x_{*t+1} and x_{*t+1}^*, respectively.

The equilibrium version of the Home household's budget constraint in nominal terms is:

[6]We assume that prices are denominated in units of the relevant country's currency. Money serves the sole purpose of unit of account in our model. Therefore, we do not model the demand for cash, and we resort to a cashless environment as in Woodford (2003). Since we assume that all prices and wages are fully flexible, we will focus only on real variables in solving the model.

$$(V_t + D_t + \varepsilon_t D_t^*)x_t + (\varepsilon_t V_t^* + D_{*t} + \varepsilon_t D_{*t}^*)x_t^* + W_t L_t = V_t x_{t+1} + \varepsilon_t V_t^* x_{t+1}^* + P_t C_t + P_t G_t,$$

where ε_t is the exchange rate (units of Home currency per unit of Foreign). We assume that all the profits generated by firms are paid to households as dividends.[7] Reflecting the multinational nature of production, D_t is the profit generated by Home firms in Home, and D_t^* is the profit generated by Home firms in Foreign. Similarly, D_{*t}^* and D_{*t} are the profits generated by Foreign firms in Foreign and Home, respectively. V_t and V_t^* are prices of shares in Home and Foreign firms, and W_t is the Home nominal wage. Dividing by P_t converts this budget constraint into units of Home consumption:

$$(v_t + d_t + d_t^*)x_t + (v_t^* + d_{*t} + d_{*t}^*)x_t^* + w_t L_t = v_t x_{t+1} + v_t^* x_{t+1}^* + C_t + G_t,$$

where w_t is the Home real wage.

The representative Home household chooses C_t, L_t, x_{t+1}, and x_{t+1}^*. The maximization problem results in the first-order conditions:

$$L_t^{\frac{1}{\varphi}} = \frac{C_t^{-\frac{1}{\sigma}} w_t}{\chi},$$
$$C_t^{-\frac{1}{\sigma}} = \beta E_t\left(C_{t+1}^{-\frac{1}{\sigma}} R_{t+1}\right), \text{ and}$$
$$E_t\left(C_{t+1}^{-\frac{1}{\sigma}} R_{t+1}\right) = E_t\left(C_{t+1}^{-\frac{1}{\sigma}} R_{t+1}^*\right),$$

where $R_t \equiv (v_t + d_t + d_t^*)/v_{t-1}$ is the gross return from holding Home firm equity, and $R_t^* \equiv (v_t^* + d_{*t} + d_{*t}^*)/v_{t-1}^*$ is the gross return from holding Foreign firm equity. The first equation gives the optimal labor supply. This is the *total* Home labor supply, comprising labor supplied to both Home and Foreign firms in Home. The second equation is the Euler equation for equity in Home firms. The third equation says that, at an optimum, Home households are indifferent between holding Home and Foreign equity. Similar equations hold for the Foreign household. For example, the Euler equation for the Foreign household's holdings of shares in Home firms is $C_t^{*-\frac{1}{\sigma}} = \beta E_t\left(C_{t+1}^{*-\frac{1}{\sigma}} R_{t+1}^f\right)$, where $R_t^f \equiv (v_t^f + d_t^f + d_t^{f*})/v_{t-1}^f$ is the return measured in units of Foreign consumption (denoted by the superscript f). This Euler equation can be expressed in units of Home consumption as $C_t^{*-\frac{1}{\sigma}} = \beta E_t\left(C_{t+1}^{*-\frac{1}{\sigma}} R_{t+1} \frac{Q_t}{Q_{t-1}}\right)$, where $Q_t \equiv \frac{\varepsilon_t P_t^*}{P_t}$ is the real exchange rate, and returns are such that $R_t = \frac{Q_t}{Q_{t-1}} R_t^f$.

The budget constraint can be used to derive the law of motion for net foreign assets:

[7] We leave retained earnings as a topic for future research.

$$nfa_{t+1} = R_t^D \alpha_t + R_t nfa_t + y_t - C_t - G_t,$$

where net foreign assets are defined as the difference between Home holdings of Foreign equity minus Foreign holdings of Home equity (adjusted for relative population size): $nfa_{t+1} \equiv v_t^* x_{t+1}^* - \frac{1-a}{a} v_t x_{*t+1}$. The superscript D denotes the difference between Home and Foreign variables, so $R_t^D \equiv R_t^* - R_t$ is the excess return on Foreign equity. Home's gross domestic product (GDP) is $y_t \equiv d_t + d_t^* + w_t L_t$.[8]

The portfolio variable α_t is defined as the Home household's holdings of Foreign firm shares multiplied by the price of Foreign shares: $\alpha_t \equiv v_{t-1}^* x_t^*$. The higher α_t, the more Foreign equity (in terms of value) Home households are holding. The portfolio held by Foreign households, α_t^*, satisfies the market-clearing condition $\alpha_t^* = -\frac{a}{1-a}\alpha_t \equiv -\frac{a}{1-a} v_{t-1}^* x_t^*$. This means that a higher α_t translates into a lower α_t^* with Foreign households owning less Foreign equity.

A similar law of motion can be derived for Foreign net foreign assets:

$$nfa_{t+1}^{*f} = R_t^{Df} \alpha_t^{*f} + R_t^f nfa_t^{*f} + y_t^{*f} - C_t^{*f} - G_t^{*f},$$

or, in units of Home consumption:

$$Q_t nfa_{t+1}^{*f} = \frac{Q_t}{Q_{t-1}} R_t^{Df} Q_{t-1} \alpha_t^{*f} + \frac{Q_t}{Q_{t-1}} R_t^f Q_{t-1} nfa_t^{*f} + Q_t y_t^{*f} - Q_t C_t^{*f} - Q_t G_t^{*f}.$$

Subtracting this equation from the law of motion for Home net foreign assets and imposing clearing of asset markets yields:

$$nfa_{t+1} = R_t^D \alpha_t + R_t nfa_t + (1-a)[(y_t - Q_t y_t^{*f}) - (C_t - Q_t C_t^{*f}) - (G_t - Q_t G_t^{*f})].$$

This law of motion for net foreign assets is the starting point for the derivation of the steady-state home optimal portfolio α.

[8] We assume that firms repatriate profits to their countries of origin for distribution to domestic and foreign shareholders. Therefore, the Home firms' profits generated in the Foreign country become a part of Home's GDP while the Foreign firms' profits generated in Home become a part of Foreign's GDP. Exploring the consequences of alternative assumptions will be a topic for future work.

2.2 Firms

Firms are monopolistically competitive. Each firm produces a differentiated good in the continuum $[0, 1]$. Home firms, denoted by z, comprise the interval $[0, a)$. Foreign firms, denoted by z^*, comprise the interval $[a, 1]$.

In contrast to GLR, where firms produce domestically and serve foreign markets by exporting, firms in our model produce in both countries. They hire labor in both countries and sell products locally in the market in which they produce.

The revenue of Home firm z, consists of the revenue earned in Home and the revenue earned in Foreign. In units of Home currency, the revenue earned in Home is $p_t(z)Z_tL_t(z)$, because the firm employs Home labor, $L_t(z)$, with exogenous Home productivity, Z_t, to produce its output in the Home country. This output is then multiplied by the price charged by the firm in in Home, $p_t(z)$. The revenue earned in Foreign is $p_t^*(z)Z_t^\gamma Z_t^{*1-\gamma}L_t^*(z)$: The firm employs Foreign labor, $L_t^*(z)$, with productivity $Z_t^\gamma Z_t^{*1-\gamma}$, where Z_t^* is Foreign productivity and $0 \leq \gamma \leq 1$. Overseas production generally implies a transfer of technology, and the output of Home firms in the Foreign country reflects a combination of Home and Foreign technologies. This output is then multiplied by the price charged by the Home firm in Foreign, $p_t^*(z)$. The firm's costs consist of the wage bill paid in Home, $W_tL_t(z)$, and that paid in Foreign, $W_t^*L_t^*(z)$. Thus, total profit, in units of Home currency, is $p_t(z)Z_tL_t(z) + \varepsilon_tp_t^*(z)Z_t^\gamma Z_t^{*1-\gamma}L_t^*(z) - W_tL_t(z) - \varepsilon_tW_t^*L_t^*(z)$. The firm maximizes this expression subject to the market clearing conditions that impose equalization of output supply (denoted with superscript s) and demand (superscript d) within each market: $Y_t^s(z) = Y_t^d(z)$ and $Y_t^{s*}(z) = Y_t^{d*}(z)$.

Similarly, Foreign firm z^* maximizes $p_{*t}(z^*)Z_t^{1-\gamma}Z_t^{*\gamma}L_{*t}(z^*) + \varepsilon_tp_{*t}^*(z^*)Z_t^*L_{*t}^*(z^*) - W_tL_{*t}(z^*) - \varepsilon_tW_t^*L_{*t}^*(z^*)$ subject to $Y_{*t}^s(z^*) = Y_{t*}^d(z^*)$ and $Y_{*t}^{*s}(z^*) = Y_{t*}^{*d}(z^*)$, where $p_{*t}(z^*)$ and $p_{*t}^*(z^*)$ are the prices charged in the Home and Foreign countries, respectively, and $L_{*t}(z^*)$ and $L_{*t}^*(z^*)$ denote labor employed in Home and in Foreign.

To reiterate, firms produce using a "mix" of Home and Foreign technologies when operating abroad. This captures the fact that the production of MNC subsidiaries is likely to be affected by both local technology (or local labor force productivity) and the technology of the MNC parent companies. Table 1 summarizes the structure of production of Home and Foreign firms in our model.

Table 1: Production structure of firms

	Home firm z	Foreign firm z^*
Home country	$y_t(z) = Z_t L_t(z)$	$y_{*t}(z^*) = Z_t^{1-\gamma} Z_t^{*\gamma} L_{*t}(z^*)$
Foreign country	$y_t^*(z) = Z_t^{\gamma} Z_t^{*1-\gamma} L_t^*(z)$	$y_{*t}^*(z^*) = Z_t^* L_{*t}^*(z^*)$

Optimally set prices equal marginal costs multiplied by constant markups. We focus on real prices expressed relative to the price index in each country in which firms operate. Home firms charge $RP_t = \frac{\theta}{\theta-1}\frac{w_t}{Z_t}$ in the Home country (in units of Home consumption) and $RP_t^* = \frac{\theta}{\theta-1}\frac{w_t^*}{Z_t^{\gamma} Z_t^{*1-\gamma}}$ in Foreign (in units of Foreign consumption). Similarly, Foreign firms charge $RP_{*t} = \frac{\theta}{\theta-1}\frac{w_t}{Z_t^{1-\gamma} Z_t^{*\gamma}}$ in Home and $RP_{*t}^* = \frac{\theta}{\theta-1}\frac{w_t^*}{Z_t^*}$ in Foreign.

In this model, no goods cross the border because the firms serve the market in each country by producing in that market. The marginal costs of producing a given good can differ between the Home and Foreign markets, and firms can charge different prices for the same good in the two markets. This goods market segmentation means that the law of one price does not have to hold. Therefore, although we are assuming that consumption preferences are identical in both countries, purchasing power parity does not have to hold. This stands in contrast to GLR, where the law of one price and purchasing power parity hold because firms serve foreign markets by exporting, and there is no difference in the marginal cost of production for domestic or export sale.

Aggregate per capita labor demand in Home, L_t^d, consists of the optimal labor demands of Home and Foreign firms in the Home market: $L_t^d = \frac{a}{a} RP_t^{-\omega} \frac{a(C_t+G_t)}{Z_t} + \frac{1-a}{a} RP_{*t}^{-\omega} \frac{a(C_t+G_t)}{Z_t^{1-\gamma} Z_t^{*\gamma}}$ where we make it transparent that we multiply the representative firms' labor demands by the numbers of firms and divide by the number of households. Similarly, aggregate per capita labor demand in Foreign, L_t^{*d}, consists of the optimal labor demands of Home and Foreign firms in Foreign: $L_t^{*d} = \frac{a}{1-a} RP_t^{*-\omega} \frac{(1-a)(C_t^*+G_t^*)}{Z_t^{\gamma} Z_t^{*1-\gamma}} + \frac{1-a}{1-a} RP_{*t}^{*-\omega} \frac{(1-a)(C_t^*+G_t^*)}{Z_t^*}$.

2.3 Shocks

The model includes four exogenous shocks: G_t, G_t^*, Z_t, and Z_t^*. All shocks follow AR(1) processes in logs. Since there are only two assets (shares in Home and Foreign firms), this guarantees that asset markets are incomplete.

3 Model Properties and Key Analytical Results

This section begins by showing properties that are useful in solving the model and interpreting its results. It then shows that, in our model, the optimal portfolio of the Home household contains no shares of Foreign equity, i.e., that optimal portfolio holdings are fully home-biased. We explain that this arises from the firms serving foreign markets by producing locally (rather than by producing domestically and then exporting their output). We then discuss how the multinational structure of firms nevertheless results in full risk sharing and the complete market outcome with no movement of net foreign assets in response to shocks.

3.1 Useful Properties

3.1.1 Relative GDP, and Relative Wages

To derive the optimal Home portfolio, α, it will be useful to have expressions for relative GDP, y_t/y_t^*, and consumption, C_t/C_t^*. The Home GDP, y_t, consists of output produced by the Home and Foreign firms in the Home country: $y_t = RP_t Z_t L_t + RP_{*t} Z_t^{1-\gamma} Z_t^{*\gamma} L_{*t}$, where the relative prices convert output of differentiated goods into units of Home consumption. Substituting the expressions for RP_t and RP_{*t} gives $y_t = \frac{\theta}{\theta-1}(w_t L_t + w_t L_{*t})$. Similarly, Foreign GDP, y_t^*, consists of output produced by Home and Foreign firms in Foreign: $y_t^* = RP_t^* Z_t^{\gamma} Z_t^{*1-\gamma} L_t^* + RP_{*t}^* Z_t^* L_{*t}^* = \frac{\theta}{\theta-1}(w_t^* L_t^* + w_t^* L_{*t}^*)$ in units of Foreign consumption.

Relative GDP is then $y_t/y_t^* = [w_t(L_t + L_{*t})]/[w_t^*(L_t^* + L_{*t}^*)]$. After substituting expressions for w_t, w_t^*, $(L_t + L_{*t})$, and $(L_t^* + L_{*t}^*)$, and imposing labor market equilibrium, the following expression is obtained:

$$\frac{y_t}{y_t^*} = \left[\frac{C_t}{C_t^*}\right]^{\frac{\varphi(1-\omega)}{\sigma(\varphi+\omega)}} \left[\frac{C_t+G_t}{C_t^*+G_t^*}\right]^{\frac{1+\varphi}{\varphi+\omega}} \left[\frac{[aZ_t^{\omega-1}+(1-a)(Z_t^{1-\gamma}Z_t^{*\gamma})^{\omega-1}]}{[a(Z_t^{\gamma}Z_t^{*1-\gamma})^{\omega-1}+(1-a)Z_t^{*\omega-1}]}\right]^{\frac{1+\varphi}{\varphi+\omega}}.$$

This expression relates the GDP ratio to consumption, government spending, and technology in the two countries.

Using the definition of the real exchange rate, the expressions for the price indices and optimal price setting, and imposing labor market clearing also makes it possible to show that relative consumption is such that:

$$\left(\frac{C_t}{C_t^*}\right)^{\frac{\varphi}{\sigma}} = \left[\frac{C_t+G_t}{C_t^*+G_t^*}\right]^{-1}\left[\frac{aZ_t^{\omega-1}+(1-a)(Z_t^{1-\gamma}Z_t^{*\gamma})^{\omega-1}}{a(Z_t^{\gamma}Z_t^{*1-\gamma})^{\omega-1}+(1-a)Z_t^{*\omega-1}}\right]^{\frac{1+\varphi}{\omega-1}}.$$

These two equations together imply:

$$\frac{y_t}{y_t^*} = \frac{C_t+G_t}{C_t^*+G_t^*}.$$

Relative GDP is pinned down by relative absorption for consumption and government spending in each country. This relative GDP expression, intuitively consistent with a world of no trade, will provide insights into the results in Section 3.2.

We also show in the Technical Appendix that the wage ratio between the two countries is entirely determined by production technologies and is independent from government spending shocks:

$$\frac{w_t}{w_t^*} = \left(\frac{a}{1-a}\right)^{\frac{1}{\omega-1}}\left[\frac{Z_t^{\omega-1}+\frac{1-a}{a}(Z_t^{1-\gamma}Z_t^{*\gamma})^{\omega-1}}{\frac{a}{1-a}(Z_t^{\gamma}Z_t^{*1-\gamma})^{\omega-1}+Z_t^{*\omega-1}}\right]^{\frac{1}{\omega-1}}.$$

3.1.2 Income Distribution

It will also be useful to take advantage of the fact that income distribution is determined by constant proportions, which is a feature of monopolistic competition with constant markups. Income consists of labor income and dividend income. As derived in Section 3.1.1, Home GDP (in units of Home consumption) equals $y_t = \frac{\theta}{\theta-1}(w_t L_t + w_t L_{*t})$. Therefore, the total Home labor income equals $w_t L_t + w_t L_{*t} = \frac{\theta-1}{\theta} y_t$, which shows that the share of labor income in Home GDP is a constant proportion $\frac{\theta-1}{\theta}$. The profit of Home firms, consisting of the profit generated in the Home and Foreign markets, equals $d_t + d_t^* = y_t - y_t\frac{\theta-1}{\theta} = \frac{1}{\theta}y_t$, which shows that the dividend income generated by Home firms is a constant proportion $\frac{1}{\theta}$ of Home GDP.[9]

[9]See the Technical Appendix for more details.

Similarly, Foreign GDP (in units of Foreign consumption) is $y_t^* = \frac{\theta}{\theta-1}(w_t^* L_t^* + w_t^* L_{*t}^*)$. Labor income then equals $\frac{\theta-1}{\theta} y_t^* Q_t$ in units of Home consumption. The profit of Foreign firms, comprising of the profit generated in the Home and Foreign markets, $d_{*t} + d_{*t}^*$, in units of Home consumption, is then $\frac{1}{\theta} y_t^* Q_t$.

The derivation of the optimal portfolio held by Home households requires obtaining an expression for the relative profit of Home and Foreign firms, $\frac{d_t + d_t^*}{d_{*t} + d_{*t}^*}$. Since $\frac{d_t + d_t^*}{d_{*t} + d_{*t}^*} = \frac{y_t}{y_t^* Q_t}$, this derivation can utilize the relative GDP expression shown in Section 3.1.1.

3.2 Optimal Portfolio and Risk Sharing

We now turn to the properties of our model for optimal equity portfolios, risk sharing, and the dynamics of net foreign assets. The standard technique for obtaining steady-state optimal portfolios in open economy macro models, developed by Devereux and Sutherland (2011) and Tille and van Wincoop (2010), combines second-order approximation of portfolio optimality conditions with log-linear approximation of the rest of the model. As we shall see, results from log-linear approximations are sufficient in the environment of our paper. The details of the solution can be found in the Technical Appendix. We present only key steps and results here.

The portfolio denoted by α_t is defined in Section 2.1 as the Home household's holdings of Foreign firm shares multiplied by the price of the Foreign firm shares, $\alpha_t \equiv v_{t-1}^* x_t^*$. Households choose the optimal portfolio in order to insure against shocks to productivity and government spending at Home and abroad: Z_t, Z_t^*, G_t, and G_t^*. Log-linearizing the law of motion for net foreign assets from Section 2.1 around a symmetric steady state with zero net foreign assets results in:

$$n\widehat{f}a_{t+1} = \frac{\alpha}{\beta(1-G)} \widehat{R}_t^D + \frac{1}{\beta} n\widehat{f}a_t + \frac{1-a}{1-G} \widehat{y}_t^D - (1-a)\widehat{C}_t^D - \frac{(1-a)G}{1-G} \widehat{G}_t^D,$$

where hats denote percentage deviations from steady state, variables without the time subscript denote steady-state levels, the superscripts D denote differences between Home and Foreign variables, and $\widehat{R}_t^D$ is the excess return.[10]

[10] As GLR, we do not introduce in the model any stationarity-inducing device that would pin down endogenously the steady-state level of net foreign assets. This means that the zero net foreign asset positions

Log-linearizing the relative-consumption equation from Section 3.1.1 yields the solution for the consumption differential as a function of relative technology and government spending:

$$\widehat{C}_t^D = \frac{(1+\varphi)(1-\gamma)}{1-G+\frac{\varphi}{\sigma}}\widehat{Z}_t^D - \frac{G}{1-G+\frac{\varphi}{\sigma}}\widehat{G}_t^D.$$

In turn, using this and the properties of relative GDP described above results in:

$$\widehat{y}_t^D = \frac{(1-G)(1+\varphi)(1-\gamma)}{1-G+\frac{\varphi}{\sigma}}\widehat{Z}_t^D + \frac{G\frac{\varphi}{\sigma}}{1-G+\frac{\varphi}{\sigma}}\widehat{G}_t^D,$$

and substituting these expressions in the log-linear net foreign asset equation yields:

$$n\widehat{f}a_{t+1} = \frac{1}{\beta}n\widehat{f}a_t + \frac{\alpha}{\beta(1-G)}\widehat{R}_t^D.$$

The Technical Appendix also shows that, as in Devereux and Sutherland (2011) and Tille and van Wincoop (2010), the excess return $\widehat{R}_t^D$ is a linear function of unexpected innovations to relative productivity and government spending. Given $\beta < 1$, this implies that α must equal zero in order to avoid net foreign assets exploding with certainty: The optimal portfolio contains no shares of Foreign firms, indicating that 100 percent Home equity bias is optimal for Home households.[11]

This result arises because firms serve foreign markets by producing locally (rather than by producing domestically and then exporting their output). Home households can diversify risk by holding a portfolio consisting of only Home firm shares because the multinational nature of firms provides exposure not only to Home productivity and government spending shocks but also to Foreign shocks through a production function that uses Foreign labor and comprises a mix of Home and Foreign technologies when operating in the Foreign country.[12]

is selected as a matter of analytical convenience, and net foreign assets (if they move) display a unit root. We make this modeling choice since our primary focus is on portfolio composition rather than the steady-state level of net foreign assets, and we aim to keep results and comparison with the GLR scenario fully transparent. Since steady state net foreign assets are zero, we define $n\widehat{f}a_t \equiv dnfa_t/C$.

[11]By comparison, the Home country's optimal portfolio in GLR is: $\alpha = \frac{\beta(1-a)}{1-\beta}[1 - \frac{G^2(\omega+\varphi)\varphi(1-\beta\phi_Z)^2\sigma^2_{\varepsilon GD}}{\sigma(\omega-1)(1+\varphi)^2(1-G)(1-\beta\phi_G)^2\sigma^2_{\varepsilon ZD}}]$, where ϕ_Z and ϕ_G denote the persistence of relative productivity and government spending shocks, and $\sigma^2_{\varepsilon ZD}$ and $\sigma^2_{\varepsilon GD}$ are the variances of i.i.d, zero-mean, normal innovations to relative productivity and government spending.

[12]Note that the optimal portfolio does not consist of only Foreign firm shares because this would not insure against the shocks related to the domestic production by the Home firm in order to supply the Home market.

Given $\alpha = 0$ and a zero initial level of net foreign assets, it follows that net foreign assets do not move in response to shocks and remain at zero in all periods. Intuitively, in a world in which countries do not trade goods (and therefore never generate future export revenues with which to repay current deficits), it is optimal—and necessary for intertemporal sustainability of otherwise-exploding net asset imbalances—never to incur movements in net foreign assets. This is consistent with the GDP ratio expression $\frac{y_t}{y_t^*} = \frac{C_t+G_t}{C_t^*+G_t^*}$ obtained above.

We next show that the optimality of complete Home equity bias arises because the multinational structure of production leads to perfect risk sharing via the real exchange rate. As noted above, the real exchange rate fluctuates in our model because domestic and foreign consumption baskets incorporate different productivity contents across countries, and there is no trade in goods that would enforce the law of one price. Straightforward substitution of the expressions for price indices from Section 2.1 yields:

$$Q_t \equiv \frac{\varepsilon_t P_t^*}{P_t} = [\frac{a(\varepsilon_t P_{Ht}^*)^{1-\omega}+(1-a)(\varepsilon_t P_{Ft}^*)^{1-\omega}}{aP_{Ht}^{1-\omega}+(1-a)P_{Ft}^{1-\omega}}]^{\frac{1}{1-\omega}} =$$
$$= [(\frac{\varepsilon_t W_t^*}{W_t})^{1-\omega}\frac{a(Z_t^{\gamma}Z_t^{*1-\gamma})^{\omega-1}+(1-a)Z_t^{*\omega-1}}{aZ_t^{\omega-1}+(1-a)(Z_t^{1-\gamma}Z_t^{*\gamma})^{\omega-1}}]^{\frac{1}{1-\omega}}.$$

Log-linearizing the Euler equations for Home and Foreign households and considering the difference between Home and Foreign results in:

$$E_t(\widehat{C}_{t+1}^D - \widehat{C}_t^D) = \sigma E_t(\widehat{Q}_{t+1} - \widehat{Q}_t).$$

Combining this expression with the solution for the consumption differential as a function of relative productivities and government shocks, $\widehat{C}_t^D = \frac{(1+\varphi)(1-\gamma)}{1-G+\frac{\varphi}{\sigma}}\widehat{Z}_t^D - \frac{G}{1-G+\frac{\varphi}{\sigma}}\widehat{G}_t^D$, implies:

$$\widehat{C}_t^D = \sigma\widehat{Q}_t,$$

which shows that the consumption differential between Home and Foreign is tied to the real exchange rate in proportional fashion. The movements in the real exchange rate ensure optimal risk sharing even if portfolios do not include any foreign equity and without any movement of net foreign assets from the steady state.

Strikingly, multinational production causes perfect risk sharing even if the elasticity of substitution between domestic and foreign goods in consumption, ω, is different from 1. It is a well known result since CO that, when goods are delivered to foreign consumers through traditional trade, if the consumption basket takes a Cobb-Douglas form, movements in the terms of trade yield the complete markets allocation in absence of any asset trade. In our model, there is no trade in goods because all consumption is produced locally, but the multinational structure of production suffices to replicate the complete markets outcome. To the best of our knowledge, this counterpart to the CO result for a world of offshore production is a novel theoretical result of our paper.[13]

4 Impulse Responses

The strategy used by firms to serve foreign markets and the production structure of firms affect the responses to business cycle shocks. We illustrate this point in this Section by showing impulse responses to productivity and government spending shocks under different assumptions: With respect to foreign sale strategy, we compare the scenario of this paper (in which firms serve markets by producing locally) to the scenario in GLR (in which firms serve foreign markets by exporting); within the local production setup of this paper, we consider cases ranging from both Home and Foreign firms using only local technology when producing in any given country ($\gamma = 0$) to the opposite extreme in which firms use only source-country technology ($\gamma = 1$). We present impulse responses to a Home technology shock in Section 4.1 and a Home government spending shock in Section 4.2. As in GLR, we focus on the responses of cross-country differentials. It is well known since Aoki (1981) that the responses of country-level variables can be recovered from those of differentials and world aggregates. We verify in the Technical Appendix that serving foreign markets by producing locally does not imply differences in the responses of world aggregates relative to serving foreign markets by exporting as in GLR. Put differently, changing the structure of production and demand-fulfillment to the one we are studying in this paper matters for how world production and consumption are allocated between the two countries but not for the overall amount of production and consumption. Hence, differences in the behavior of cross-country differentials contain all the information that would be needed to study also

[13] It is worth noting here that the Devereux and Sutherland (2011)-Tille and van Wincoop (2010) technique cannot pin down the optimal portfolio α in our model because neither $\widehat{C}_{t+1}^D$ nor $\widehat{R}_{t+1}^D$ in the second-order equation $E_t(\widehat{C}_{t+1}^D \widehat{R}_{t+1}^D) = 0$ contain α.

differences in the responses of country-level variables between the two models. We use the same values as in GLR for the parameters that appear in both models for transparency of comparison. The parameter values that are relevant to compute the responses of cross-country differentials to shocks are listed in Table 4.[14]

Table 2: Parameter values

Parameter	Value
Discount factor, β	0.99
Elasticity of intertemporal substitution, σ	0.5
Frisch elasticity of labor, φ	4.0
Share of government spending in GDP, G	0.2
Persistence of relative productivity process, ϕ_Z	0.95
Persistence of relative government spending process, ϕ_G	0.78

This table shows parameter values used to generate the impulse response functions. The parameter values are adopted from Ghironi et al. (2015).

4.1 Technology Shock

Figure 1 shows impulse responses to a 1-percent relative technology shock, Z^D. (Absent Foreign shocks and spillover effects, Home technology shocks are also shocks to relative technology.) The top left panel shows the response of the cross-country GDP differential. In general, an improvement in Home technology causes Home GDP to increase relative to Foreign, but important differences emerge across scenarios. The GDP differential is most pronounced in the GLR world (gray line), in which Foreign firms and labor receive no productive benefit from the improvement in Home technology. Offshore production dampens the response of relative GDP, the more so the more firms use source-country technology. This can be seen from the expression for $\widehat{y}_t^D$, which (absent shocks to government spending) reduces to $\widehat{y}_t^D = \frac{(1-G)(1+\varphi)(1-\gamma)}{1-G+\frac{\varphi}{\sigma}}\widehat{Z}_t^D$. When $\gamma = 1$ (red line with diamonds), firms use only their own country's technology regardless of where they produce, and $\widehat{y}_t^D = 0$. In this case, an improvement in Home technology does not generate any GDP differential because

[14]The other parameters in the model (the size of the Home and Foreign economies, a, the elasticity of substitution between individual goods within each country, θ, and the elasticity of substitution between Home and Foreign goods, ω) are not relevant to compute the responses we are focusing on in our model. They are necessary, however, to compute the responses in the GLR scenario, where they are set to 0.5, 6, and 2, respectively.

the technological improvement affects equally the effectiveness of Home and Foreign labor employed by Home firms. When $\gamma = 0$ (blue line with triangles), both Home and Foreign firms use only Home technology to produce in Home, and both use only Foreign technology, Z^*, to produce in Foreign. In this case, a positive shock to Home technology increases Home GDP relative to Foreign because there is no improvement in the effectiveness of Foreign labor, but the increase is less pronounced than in the GLR world because, in the offshore production scenario, the profitability of Home operations of Foreign firms rises. The green line with circles shows the impulse response for the intermediate case $\gamma = 0.5$, in which firms use a combination of domestic and foreign technology when they produced abroad.

The top right panel of the figure presents the response of the real exchange rate. Frictionless trade and identical consumer preferences across countries imply purchasing power parity in GLR. Hence, the real exchange rate does not move in the GLR world, and we report the response of the terms of trade for that case. Consistent with standard intuition, Home's terms of trade depreciate to clear the goods market as the supply of Home goods increases. In our world of offshore production, there is no trade in goods that would enforce the law of one price, and domestic and foreign consumption baskets incorporate different productivity contents across countries. As a consequence, PPP does not hold, and the real exchange rate fluctuates. An improvement in Home technology is associated with real depreciation, except in the case $\gamma = 1$: As with the absence of a GDP differential, the real exchange rate remains constant in this case because the effectiveness of Home and Foreign labor employed by Home firms is affected equally by the shock. Instead, the real exchange rate depreciates by more the more firms rely on host-country technology in overseas production. In this case, it is only the effectiveness of Home labor that is affected by the shock, but Foreign firms are using Home technology when employing Home labor. Optimal price setting in this environment implies that the Home price index falls relative to Foreign, which translates into real depreciation. As before, the intermediate case $\gamma = 0.5$ falls between the two extremes.

The consumption differential, C^D (middle left panel), varies proportionately with the real exchange rate as implied by $\widehat{C}_t^D = \sigma \widehat{Q}_t$. As we showed in Section 3.2, offshore production implies perfect risk sharing (and no movement of net foreign assets in response to shocks) even if the optimal portfolio is fully home-biased. In the incomplete-markets, GLR world of international trade, a Home technology shock causes Home consumption to rise permanently above Foreign. With offshore production, the extent to which the consumption differential moves depends on the structure of production: Equal impacts of the technology shock on the effectiveness of Home and Foreign labor ($\gamma = 1$) imply no movement of the consumption differential; otherwise, Home consumption rises above Foreign, and it does so by more if host country technology is predominantly used.

The middle right panel shows the responses of employment to the shock: In GLR, improvement in Home technology implies an increase in Home employment relative to Foreign as familiar resource-shifting (even in the presence of imperfect substitutability) implies increased production in the country that has received the favorable shock and, therefore, increased employment of its labor. The effect of the shock on relative employment with offshore production depends again on the production structure: There is no differential in employment if $\gamma = 1$, otherwise Home employment actually falls relative to Foreign. In the standard model (GLR), a relative increase in Home labor effort is also needed for Home households to make up for the loss of purchasing power implied by terms of trade depreciation. Offshore production with exclusive use of host-country technology actually implies the largest increase in the purchasing power of Home incomes, which allows Home households to sustain any given level of consumption with reduced labor effort. In turn, this is mirrored in the behavior of the wage differential: In GLR, increased employment of Home labor drives Home wages above Foreign, but the largest increase in the wage differential happens with offshore production and $\gamma = 0$—the case in which Home households enjoy the largest increase in consumption and leisure.

Finally, in GLR, an improvement in Home technology increases the value of Home equity relative to Foreign because the dividend ratio is tied to the GDP ratio, which rises. With offshore production, the ratio of total dividends generated by Home and Foreign firms measured in the same units (Home consumption) is tied to the ratio of GDPs adjusted for the real exchange rate, $\frac{y_t}{y_t^* Q_t}$. Hence, real depreciation implies that the ratio of total dividends generated by Home firms to those generated by Foreign ones falls in response to Home technological improvement (the more so the more Foreign firms use Home technology when producing in Home), and this translates into a lower relative value of Home equity.

4.2 Government Shock

Figure 2 shows impulse responses to a 1-percent relative government spending shock, G^D. The responses show that the value of γ does not affect the response of the economy to this shock. The production structure, therefore, matters for supply shocks but not for demand shocks in our model. However, the strategy used by firms to serve foreign markets matters crucially also for the transmission of demand shocks.

In the GLR world, international relative prices and cross-country differentials in macro aggregates immediately jump to their new long-run levels regardless of the actual persistence of the shock. Market incompleteness implies that the consumption differential across countries obeys a random walk and agents who fully anticipate the path of spending (and taxation) following an initial shock also adjust their labor effort permanently on impact to smooth consumption and leisure. (This instantaneous adjustment does not happen with technology shocks that affect the effectiveness of labor over time.) Home government spending expansion causes an increase in Home GDP relative to Foreign but a decrease in relative consumption as Ricardian households adjust their intertemporal behavior in standard fashion. Negative wealth effects induce Home households to increase labor supply, so Home wages fall relative to Foreign, and the terms of trade deteriorate. Higher Home GDP relative to Foreign corresponds to higher Home relative dividends, and Home equity values rise above Foreign.

Offshore production removes the random walk behavior of the consumption differential by implying perfect risk sharing and the corresponding tight link between relative consumption and the real exchange rate. This ensures that the responses of international relative prices and cross-country differences in macro aggregates to the shock are stationary and return to the initial steady state over time. The shock has no impact on the relative effectiveness of labor across countries, and therefore adjustment happens without any movement in relative wages. Whereas the terms of trade depreciate in the GLR scenario, the real exchange rate appreciates in the world of offshoring, consistent with the downward movement of Home consumption relative to Foreign. Other than this difference in international relative price behavior, the impact responses of cross-country differences in macro aggregates are intuitively in the same direction as in GLR.

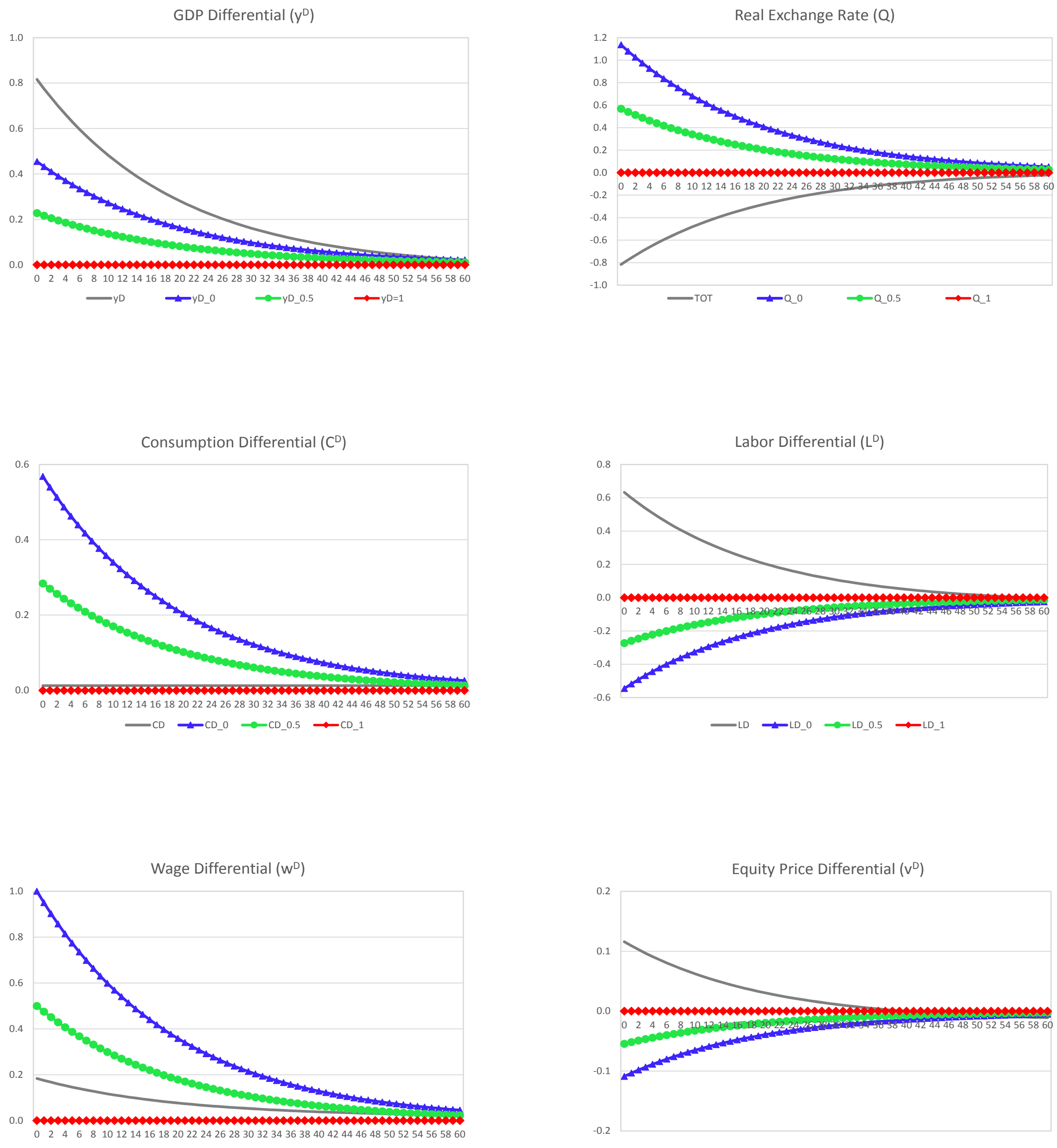
5 Conclusion

This paper studied the consequences of serving foreign markets by producing locally (offshore production) for international equity portfolios, risk sharing, and the international transmission of exogenous shocks to technology and demand (government spending). We showed that optimal portfolio decisions in a world of offshoring imply perfect risk sharing even if equity portfolios are fully home-biased. International adjustment to shocks happens without any movement in net foreign asset positions. This result is reminiscent of the finding in Cole and Obstfeld (1991) that, in the presence of unitary elasticity of substitution between domestic and foreign goods in consumption, movements in the terms of trade ensure perfect consumption risk sharing in absence of any international asset trade. In our model, there is no movement in the terms of trade, as firms serve consumers in different markets by producing locally and employing local labor, and there is no international trade in goods. However, the behavior of profits and effective labor costs across countries ensures that the same property holds—and it does so regardless of the value of substitutability between domestic and foreign goods in consumption.

We intentionally kept our model as simple as possible to obtain analytical, transparent results. A numerical illustration of responses to technology and government spending shocks allowed us to highlight the differences in international transmission of shocks between our setup and a setup in which firms serve foreign markets by exporting. This also made it possible to illustrate the importance for shock transmission of the extent to which firms use source-country versus host-country technology when producing offshore.

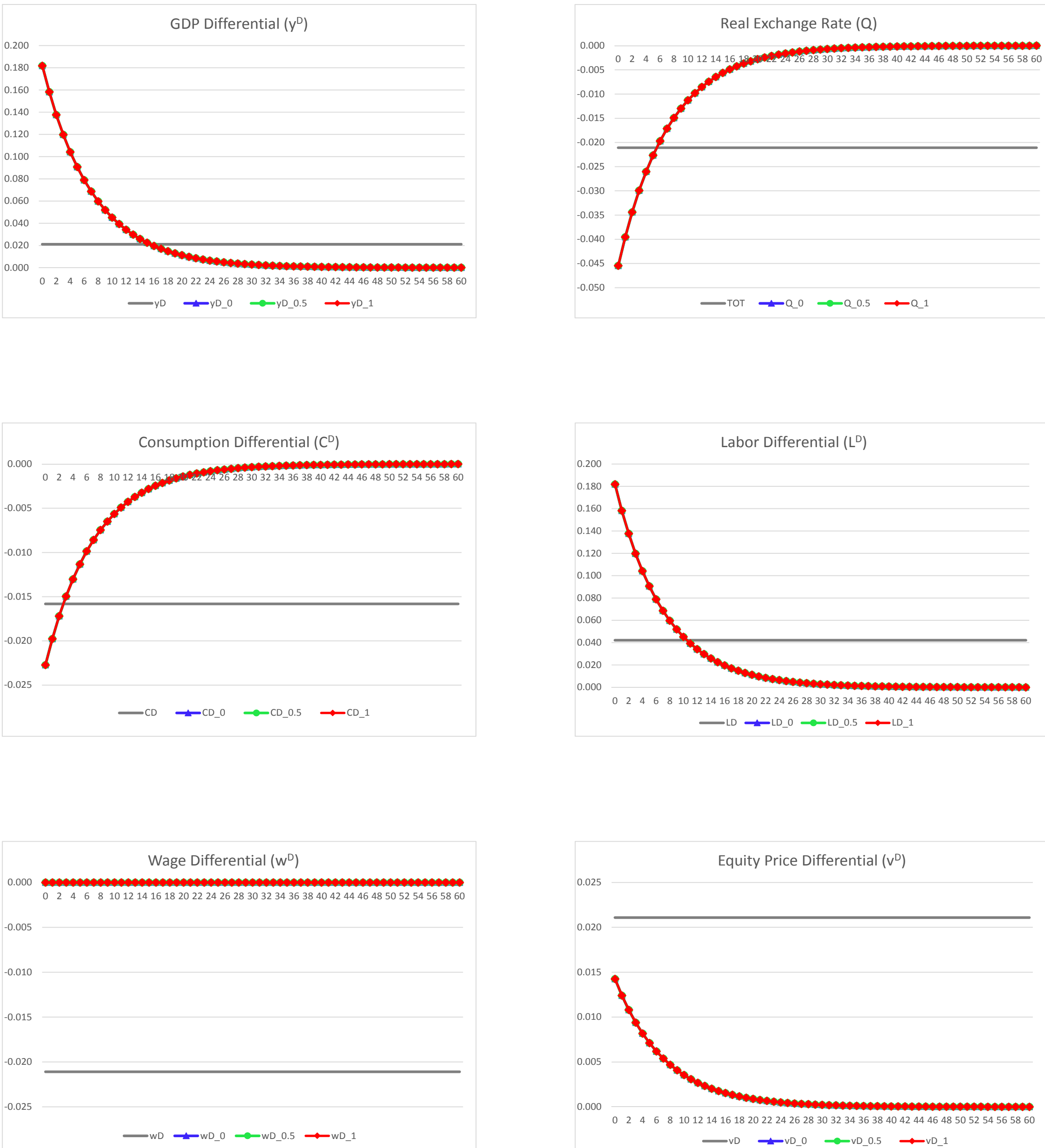
The results of this paper provide intuitions and guidance for the results of more empirically appealing, quantitative models with offshore production—including models with endogenous firm decisions on offshoring versus exporting, in which different strategies to serve foreign markets can coexist, and additional frictions are introduced.

Figure 1: Impulse Responses to a Relative Technology Shock, Z^D



This figure shows impulse responses of key variables to a 1% relative technology shock, Z^D. The horizontal axis represents sixty time periods. The blue (triangle), green (circle), and red (diamond) lines use values of $\gamma = 0$, $\gamma = 0.5$, and $\gamma = 1$, respectively. The gray line shows responses from the Ghironi et al. (2015) model for comparison.

Figure 2: Impulse Responses to a Relative Government Spending Shock, G^D



This figure shows impulse responses of key variables to a 1% relative government spending shock, G^D. The horizontal axis represents sixty time periods. The blue (triangle), green (circle), and red (diamond) lines use values of $\gamma = 0$, $\gamma = 0.5$, and $\gamma = 1$, respectively. The gray line shows responses from the Ghironi et al. (2015) model for comparison.

References

Aoki, M. (1981). *Dynamic analysis of open economies*. Amsterdam, Netherlands: Academic Press.

Benigno, G., & Thoenissen, C. (2008). Consumption and real exchange rates with incomplete markets and non-traded goods. *Journal of International Money and Finance*, *27*, 926–948.

Cole, H. L., & Obstfeld, M. (1991). Commodity trade and international risk sharing: How much do financial markets matter? *Journal of Monetary Economics*, *28*, 3–24.

Contessi, S. (2015). Multinational firms' entry and productivity: Some aggregate implications of firm level heterogeneity. *Journal of Economic Dynamics and Control*, *61*, 61–80.

Corsetti, G., Dedola, L., & Leduc, S. (2008). International risk sharing and the transmission of productivity shocks. *The Review of Economic Studies*, *75*, 443–473.

Devereux, M. B., & Sutherland, A. (2011). Country potrfolios in open economy macro-models. *Journal of the European Economic Association*, *9*, 337–369.

Errunza, V., Hogan, K., & Hung, M.-W. (1999). Can the gains from international diversification be achieved without trading abroad? *The Journal of Finance*, *54*, 2075–2107.

Fillat, J. L., & Garetto, S. (2015). Risk, returns, and multinational production. *The Quarterly Journal of Economics*, *130*, 2027–2073.

Fillat, J. L., Garetto, S., & Oldenski, L. (2015). Diversification, cost structure, and the risk premium of multinational corporations. *Journal of International Economics*, *96*, 37–54.

Ghironi, F., Lee, J., & Rebucci, A. (2015). The valuation channel of external adjustment. *Journal of International Money and Finance*, *57*, 86–114.

Helpman, E., Melitz, M. J., & Yeaple, S. R. (2004). Export versus FDI with heterogeneous firms. *American Economic Review*, *94*, 300–316.

Ramondo, N., & Rappoport, V. (2010). The role of multinational production in a risky environment. *Journal of International Economics*, *81*, 240–252.

Rowland, P. F., & Tesar, L. (2004). Multinationals and the gains from international diversification. *Review of Economic Dynamics*, *7*, 789–826.

Tille, C., & van Wincoop, E. (2010). International capital flows. *Journal of International Economics*, *80*, 157–175.

Woodford, M. (2003). *Interest and prices: Foundations of a theory of monetary policy.* Princeton, NJ: Princeton University Press.

Zlate, A. (2016). Offshore production and business cycle dynamics with heterogeneous firms. *Journal of International Economics*, *100*, 34–49.