International Portfolio Diversification and the Structure of Global Production

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Abstract

In recent decades, country portfolio home bias has fallen in advanced economies but not in emerging economies. I use a dynamic general equilibrium model to show that changes in the distribution of global production and absorption explain this pattern. For advanced economies, whose share of world output fell as their trade openness rose, the model predicts an unambiguous drop in home bias. By contrast, emerging economies' growth in both size and trade openness have opposing implications for portfolios. To quantify these forces I calibrate the model to real and counterfactual input-output tables. Jointly, changes in the global production structure account for much of the decline in home bias in advanced economies and lack thereof in emerging economies. Country size and trade openness account for most of this effect. Consistent with theory, the increase in the intermediate share of trade had little impact.

Keywords: country portfolios, international portfolio diversification, production structure
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1. Introduction

Since the 1990s, advanced economies' country portfolios have shifted towards foreign assets while emerging economies' portfolios have not. Concurrently, the structure of global production and absorption has changed in several key ways: emerging economies have grown relative to advanced economies, openness to international trade has risen, and trade consists increasingly of intermediate inputs instead of final goods. In this paper, I use theory and quantitative analysis to show that changes in the global production structure explain trends in international portfolio diversification.

Figure 1 depicts the stylized facts that motivate this study. Figure 1a shows that the mean level of international portfolio diversification, measured as the fraction of national wealth held in foreign assets, has risen dramatically in the United States and other advanced economies since the 1990s but has changed little in emerging economies and the rest of the world. Recent studies by Coeurdacier and Rey (2013) and Mukherjee (2015) have documented similar trends. Figures 1b,

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1c, and 1d show that, at the same time, the structure of global production has changed in three key ways. First, emerging economies and the rest of the world have grown relative to advanced economies. Second international trade has grown substantially.[1] Third, trade in intermediate inputs has grown faster than trade in final goods as documented by Hummels et al. (2001), Johnson (2014b), and Johnson (2014a), among others.

In the theoretical section of the paper, I derive a closed-form expression for equilibrium portfolios in a workhorse international macro model (Backus et al., 1994, 1995) with trade in intermediate inputs and an arbitrary number of symmetric countries. In this setting, equilibrium international portfolio diversification is decreasing in country size, which is inversely related to the number of countries, and increasing in trade in both final goods and intermediate inputs. These results integrate and generalize the findings of Baxter and Jermann (1997), who argue that larger countries should hold more wealth in domestic assets, and Heathcote and Perri (2013), henceforth HP, who show that openness to trade increases diversification. For advanced economies, whose share of world GDP has fallen while their openness to trade has grown, these two forces work together. For emerging economies and the rest of the world, however, who have grown in both size and trade openness, these forces work in opposition. Thus, changes in the global production structure explain why international portfolio diversification has risen in advanced economies but not in emerging economies and the rest of the world.

I also derive two new theoretical results about the effects of the global production structure on international portfolio diversification. First, openness to trade in intermediate inputs has the same impact on portfolio diversification as trade in final goods. This suggests that the increasing share of intermediate inputs in international trade has not contributed to the patterns in figure 1a. My quantitative results are consistent with this prediction. Second, trade and country size have complementary effects on portfolio diversification. This provides insight into the differences between the quantitative results for the United States and the results for other advanced economies.

In the quantitative section of the paper, I use a calibrated version of the model to assess the contributions of changes in the global production structure to changes in portfolio diversification. This version of the model features four asymmetric regions — the same four regions in figure 1 — and CES technologies that I calibrate to match input-output data from the World Input Output Database (Timmer et al., 2015). To quantify the overall impact of changes in the global production structure on international portfolio diversification, I calibrate and solve the model twice, first using the 1995 input-output table and then using the 2011 table. The differences between these two input-output tables capture all aspects of change in the global production structure between 1995 and 2011: changes in relative country size, increased trade openness, and increased trade in intermediate inputs. The difference in each region's equilibrium portfolio diversification between these two calibrations is the model's assessment of the combined impact of these changes on that region's portfolio diversification. For advanced economies, overall change in the global production structure had a large impact on portfolio diversification. For the United States, equilibrium

[1] I measure each region's openness to trade as the sum of its imports and exports as a fraction of world GDP, rather than the region's own GDP. This measure disentangles changes in region size from changes in openness; using the standard measure, a region that grows in relative size but not openness would trade more and thus affect other regions' openness. My quantitative exercise is designed with exactly this sort of disentanglement in mind.

diversification rises by 7.33 percentage points, about a fifth of the increase observed in the data. For other advanced economies, diversification rises by 18.66 percentage points, more than half of the observed increase. For emerging economies and the rest of the world, equilibrium portfolio diversification changes little in response to overall change in the global production structure, just as seen in the data.

To isolate the impacts of changes in the three features of the global production structure highlighted above — country size, trade openness, and intermediate trade — I calibrate the model to counterfactual input-output tables that I have constructed to capture what the global production structure would have looked like in 2011 had only one of these features changed at a time. Differences in equilibrium portfolio diversification between the 1995 calibration and these counterfactuals are the model's assessments of each of these features' effects on portfolio diversification. In the first counterfactual I change only each region's relative size. Consistent with Baxter and Jermann (1997)'s logic, equilibrium portfolio diversification rises in the U.S. and other advanced economies, which shrank in relative size, and falls in emerging economies and the rest of the world, which grew. In the second counterfactual I change only each region's openness to trade. As Heathcote and Perri (2013) would predict, portfolio diversification rises in all regions, with larger effects in regions whose openness grew more. In the third counterfactual I change only the fraction of each region's trade that is devoted to intermediate inputs. Consistent with my theoretical analysis, this change has little impact on portfolio diversification.

This paper contributes to several strands of literature. First and foremost, it contributes to the large literature on international portfolio diversification. Coeurdacier and Rey (2013) survey this literature and document the asymmetry between advanced and emerging economies that motivates my study. The inability of standard, one-good models to generate the degree of home bias observed in the data (Baxter and Jermann, 1997; Lewis, 1999) was once considered one of the most important puzzles in the field (Obstfeld and Rogoff, 2001). Since then, numerous studies have posed explanations for home bias in country portfolios. HP show that home bias emerges as an equilibrium outcome in standard international macro models in which domestic and foreign goods are imperfect substitutes (Backus et al., 1994, 1995). Other explanations for are sticky prices (Engel and Matsumoto, 2009), the presence of a nontraded sector (Hnatkovska, 2010), asymmetric information (Mondria and Wu, 2010; Dziuda and Mondria, 2012), and poor institutions (Mukherjee, 2015). These studies have focused on accounting for levels of portfolio home bias rather than changes as I do in this paper. HP, though, point out that "observed growth in trade. . . can explain only a small fraction of the increase in international diversification. . . Investigating the causes of the residual growth in diversification is an interesting direction for future research." My research helps fill this gap.

This paper is also related to the literature on the macroeconomic impact of increased intermediate trade. There is an active empirical literature that measures different aspects of this phenomenon, like vertical specialization (Hummels et al., 2001) and the decomposition of gross exports into domestic and foreign value added (Johnson and Noguera, 2016; Johnson, 2014a; Koopman et al., 2014; Wang et al., 2013). The input-output tables to which I calibrate my model capture change in all of these measures. Quantitative research on the implications of increased trade in intermediate inputs has focused on international transmission of aggregate shocks. Bems et al. (2010), Bems et al. (2011), Bems et al. (2013), and others have studied the role of production chains in the collapse of global trade that followed the financial crisis of 2008–2009. Other work like Arkolakis and Ramanarayanan (2009) and Johnson (2014b) study the role of production chains in synchronizing business cycles across countries. These studies typically find that intermediate trade has little impact on international business cycles. Similarly, I find that this phenomenon has little impact on portfolios.

Finally, my paper also makes a technical contribution to the literature on solving models with portfolio allocation problems. Perturbation methods that involve first-order approximations of equilibrium conditions are not suitable for solving portfolio problems; these methods cannot determine equilibrium portfolios because all assets have the same expected return. Tille and van Wincoop (2010) and Devereux and Sutherland (2011) devise similar solution methods for two-country models that use higher-order approximations of the equilibrium conditions that govern portfolio allocation. To solve for equilibrium portfolios in my model, which has four regions and an equal number of assets, I generalize the Devereux and Sutherland (2011) method to an environment with any number of agents and assets. Models of portfolio choice with many agents and/or assets are often computationally intractable when using global solution methods, so my generalized method should facilitate the investigation of a variety of interesting portfolio problems.

2. Theory

In this section I use a theoretical model to illustrate how the structure of global production affects equilibrium portfolio diversification. The model extends the workhorse international macro model studied by HP to an environment with many symmetric countries that trade intermediate inputs, final goods, and equities. The number of countries, denoted by I, governs the size of each country; as I increases each country i's size relative to the size of the world economy falls.

In each period $t = 0, 1, \ldots$ the economy experiences an exogenous event $s_t \in S$; the probability of a history $s^t = (s_0, \ldots, s_t) \in S^t$ is $\pi(s^t)$. Production firms in each country i produce gross output according to an input-output technology, combining domestic capital and labor with intermediate inputs produced both at home and abroad. Firms' total factor productivities are subject to country-specific productivity shocks that depend on the aggregate state s_t. Retailers in each country combine domestic and foreign goods to produce a nontradable final good which is used for consumption and investment. Households in each country work, consume, and trade shares in domestic and foreign production firms.

2.1. Production firms

Firms in each country i use capital, $k_i(s^t)$, labor, $\ell_i(s^t)$, and intermediate inputs from each country j, $m_{i,j}(s^t)$, to produce gross output according to the Cobb-Douglas technology

$$y_i(s^t) = \left[z_i(s^t)k_i(s^{t-1})^{\alpha}\ell_i(s^t)^{1-\alpha}\right]^{\upsilon}\left[m_{i,i}(s^t)^{\mu}\left(\prod_{j\neq i} m_{i,j}(s^t)^{\frac{1-\mu}{I-1}}\right)\right]^{1-\upsilon}. \tag{1}$$

$z_i(s^t)$ is country i's total factor productivity. In this section I assume that the stochastic process for productivity is symmetric across countries but impose no other restriction. The parameter υ

is the value added share in gross output. μ, the share of domestic inputs in the aggregate intermediate bundle, governs openness to intermediate input trade. Production firms choose factors, intermediate inputs, and investment, $x_i(s^t)$, to maximize the present value of dividends,

$$\sum_{t=0}^{\infty} \sum_{s^t \in S^t} Q_i(s^t) d_i(s^t), \tag{2}$$

subject to a sequence of budget constraints,

$$d_i(s^t) = p_{i,i}(s^t) y_i(s^t) - w_i(s^t) n_i(s^t) - \sum_{j=1}^{I} p_{i,j}(s^t) m_{i,j}(s^t) - x_i(s^t), \tag{3}$$

the usual law of motion for capital,

$$k_i(s^t) = (1-\delta) k_i(s^{t-1}) + x_i(s^t), \tag{4}$$

and the technology (1). $p_{i,j}(s^t)$ is the price of country j's output relative to country i's final good and $w_i(s^t)$ is country i's wage. $Q_i(s^t)$ is the price used to discount country i's dividends.

2.2. Retailers

Country i's final good, $g_i(s^t)$, is an Armington aggregate of purchases from each country j, $g_{i,j}(s^t)$:

$$g_i(s^t) = g_{i,i}(s^t)^{\omega} \left(\prod_{j \neq i} g_{i,j}(s^t)^{\frac{1-\omega}{1-I}} \right). \tag{5}$$

The parameter ω, the share of domestic inputs in the final demand bundle, governs openness to trade in final goods. Final demand aggregators are perfectly competitive, and choose inputs in each period to maximize profits

$$g_i(s^t) - \sum_{j=1}^{I} p_{i,j}(s^t) g_{i,j}(s^t) \tag{6}$$

subject to (5). The price of each country's final good is normalized to one as in HP.

2.3. Households

Households in each country i have preferences

$$\sum_{t=0}^{\infty} \sum_{s^t \in S^t} \pi(s^t) \beta^t u(c_i(s^t), \ell_i(s^t)) \tag{7}$$

over sequences of consumption, $c_i(s^t)$, and labor supply, $\ell_i(s^t)$. Households choose consumption, labor supply, and shares in each country j's stock, $\lambda_{i,j}(s^t)$, to maximize (7) subject to a sequence of budget constraints,

$$c_i(s^t) + \sum_{j=1}^{I} e_{i,j}(s^t) q_j(s^t) \left(\lambda_{i,j}(s^t) - \lambda_{i,j}(s^{t-1}) \right) = w_i(s^t) \ell_i(s^t) + \sum_{j=1}^{I} \lambda_{i,j}(s^{t-1}) e_{i,j}(s^t) d_j(s^t). \tag{8}$$

$q_j(s^t)$ is the price of country j's stock and $e_{i,j}(s^t)$ is the real exchange rate between country i and country j. As in HP, I assume that flow utility is given by

$$u(c_i(s^t), \ell_i(s^t)) = \log(c_i(s^t)) - h(\ell_i(s^t)) \tag{9}$$

where h is increasing and convex. This allows for analytical characterization of equilibrium portfolios which do not depend on disutility from labor supply. Also as in HP, I assume that firms use domestic households' stochastic discount factors to price dividends: $Q_i(s^t) = \pi(s^t)\beta^t c_i(s^0)/c_i(s^t)$.

2.4. *Equilibrium*

A competitive equilibrium is a sequence of prices and quantities that satisfy: (i) the first-order conditions of production firms, retailers, and households; (ii) market clearing conditions for gross output, final goods, and shares; and (iii) the law of one price. The market clearing conditions are, for each $i = 1, \ldots, I$,

$$y_i(s^t) = \sum_{j=1}^{I} \left(m_{j,i}(s^t) + g_{j,i}(s^t) \right), \tag{10}$$

$$g_i(s^t) = c_i(s^t) + x_i(s^t), \tag{11}$$

$$1 = \sum_{j=1}^{I} \lambda_{j,i}(s^t). \tag{12}$$

The law of one price requires that, for each i, j,

$$e_{i,j}(s^t) p_{j,j}(s^t) = p_{i,j}(s^t). \tag{13}$$

Equilibrium prices and allocations depend on initial conditions for each country's productivity, capital stock, and portfolio holdings. For the remainder of section 2, I assume that initial conditions for capital stocks and portfolio shares are symmetric and all countries' productivities start at their unconditional mean values.

2.5. *Characterizing equilibrium portfolios*

This environment, like that studied by HP and Heathcote and Perri (2004), admits an analytical solution for the equilibrium level of international portfolio diversification. Proposition 1 below contains this solution and Corollary 1.1 illustrates how it depends on the parameters that govern the structure of global production in the model, I, ω, and μ.

Proposition 1. There exists an efficient equilibrium in which each country holds a constant share λ of domestic stock and a constant share $(1-\lambda)/(I-1)$ of each foreign stock. International portfolio diversification in this equilibrium is given by

$$1 - \lambda = \frac{(I-1)(1 - D\omega - F(1-\omega))}{I - 1 + \alpha\left[D + (I-1)F - I(D\omega + F(1-\omega))\right]}, \tag{14}$$

where the constants D and F are defined as

$$D = \frac{1 - \mu - \mu\upsilon - (I-2)\upsilon}{I\mu + \upsilon - I\mu\upsilon - I}, \tag{15}$$

$$F = \frac{(1-\upsilon)(\mu - 1)}{I\mu + \upsilon - I\mu\upsilon - I}. \tag{16}$$

Proof. See the online appendix.

Corollary 1.1. If there is home bias in final demand ($\omega > 1/I$) and in intermediate usage ($\mu > 1/I$), equilibrium international portfolio diversification has the following properties:

$$(a)\ \frac{\partial(1-\lambda)}{\partial I} > 0, \quad (b)\ \frac{\partial(1-\lambda)}{\partial \omega} > 0, \quad (c)\ \frac{\partial(1-\lambda)}{\partial \mu} > 0,$$

$$(d)\ \frac{\partial^2(1-\lambda)}{\partial\omega\partial I} > 0, \quad (e)\ \frac{\partial^2(1-\lambda)}{\partial\mu\partial I} > 0.$$

2.6. Discussion

The results above integrate and generalize those of Baxter and Jermann (1997) and HP. Baxter and Jermann (1997) study a many-country, one-sector model in which domestic and foreign products are perfect substitutes. Larger countries should have less internationally diversified portfolios, they argue, because such countries account for larger shares of world stock market capitalization. Property (a) of Corollary 1.1 captures this argument. HP study a two-country model in which domestic and foreign products are imperfect substitutes and find that portfolio diversification is increasing in international trade in final goods. Property (b) captures this finding exactly. Their solution for equilibrium portfolios is, in fact, a special case of equation (14) with two countries ($I = 2$) and no intermediate inputs ($\upsilon = 1$).

Properties (c)–(e) are novel results. Property (c) implies that trade in intermediates inputs has the same impact on portfolio diversification as trade in final goods. This is consistent with my quantitative finding that the shift towards intermediate trade has had little impact on country portfolios. Properties (d)–(e) imply that country size and trade openness have complementary effects on portfolio diversification. As we will see, these properties provide useful insight into the differences between the quantitative results for the United States, whose size and trade openness have changed modestly, and the results for other advanced economies, whose size and openness have changed significantly.

Putting these properties together, we can see how changes in the global production structure explain the increase in portfolio diversification in advanced economies and the lack thereof in emerging economies and the rest of the world. For advanced economies, whose shares of world output have shrunk while their openness to trade has grown, properties (a)–(c) of Corollary 1.1 unambiguously predict rising diversification, just as we see in the data. For emerging economies and the rest of the world, however, who have grown in both size and openness, property (a) has the opposite impact of properties (b) and (c). Consequently, the model does not make an unambiguous prediction about the change in portfolio diversification in emerging economies and the rest of the world; quantitative analysis is necessary to investigate the contributions of each of these forces. I take up that task in section 3.

2.7. *Risk sharing intuition*

Before turning to the quantitative analysis, however, I will first use risk-sharing theory to derive some intuition for Proposition 1 and Corollary 1.1. Following HP, let $\Delta c_{i,j}(s^t)$ denote the exchange-rate adjusted difference between consumption in country i and consumption in country j: $\Delta c_{i,j}(s^t) = c_i(s^t) - e_{i,j}(s^t)c_j(s^t)$. Similarly, let $\Delta y_{i,j}(s^t)$ and $\Delta x_{i,j}(s^t)$ denote differences in nominal gross output and investment. Subtracting country j's budget constraint from country i's and assuming constant, symmetric portfolios, we find that

$$\Delta c_{i,j}(s^t) = \upsilon \left\{ 1 - \alpha \left[1 - \left(\frac{1 - I\lambda}{I - 1} \right) \right] \right\} \Delta y_{i,j}(s^t) + \left(\frac{1 - I\lambda}{I - 1} \right) \Delta x_{i,j}(s^t). \tag{17}$$

When $I = 2$ and $\upsilon = 1$, this equation reduces to HP's equation (18). Since the equilibrium exhibits perfect risk sharing, $\Delta c_{i,j}(s^t) = 0$ for all i, j and all s^t.

In a one-good Lucas-tree model like that studied by Baxter and Jermann (1997), $e_{i,j}(s^t)$ always equals 1 and $\Delta x_{i,j}(s^t)$ always equals zero. In this case, perfect risk sharing implies that the solution for λ must set the coefficient on $\Delta y_{i,j}(s^t) = 0$. The solution is the same portfolio described in Baxter and Jermann (1997): $1 - \lambda = (I - 1)/(I\alpha)$.[2] It entails a short position in domestic stock because labor and capital income are perfectly correlated. As the number of countries grows, international portfolio diversification rises; smaller countries have larger short positions in domestic stock. This accounts for property (a) in Corollary 1.1.

In the model studied in this paper with Cobb-Douglas technologies and roundabout production, one can show that

$$\begin{aligned} \Delta c_{i,j}(s^t) \propto & - \Delta x_{i,j}(s^t) + \left(\frac{1 - I\lambda}{I - 1} \right) \Delta x_{i,j}(s^t) + \\ & \upsilon \left\{ 1 - \alpha \left[1 - \left(\frac{I\lambda - 1}{I - 1} \right) \right] \right\} \left[\frac{I(D\omega + F(1 - \omega)) - 1}{I - 1} \right] \Delta x_{i,j}(s^t)). \end{aligned} \tag{18}$$

When portfolios are given by the solution in Proposition 1 the right hand side of this expression is always equal to zero, confirming that this solution delivers perfect risk sharing. The last term, which HP call "indirect foreign financing," is the source of the relationship between openness to trade and portfolio diversification. To see this, consider first the case without intermediate inputs where $\upsilon = 1$, $D = 1$, and $F = 0$. If there is home bias in final demand ($\omega > 1/I$), an increase in relative investment, $\Delta x_{i,j}(s^t)$, raises relative demand for country i's output. This improves country i's terms of trade, increasing the revenues of country i's firms. The fraction of these additional revenues that accrue to domestic households is equal to the labor share plus domestic households' net claims to domestic capital income. This fraction is positive for standard values of α, yielding country portfolios with long, not short, positions in domestic stock. When openness to trade in final goods rises — when ω falls — the indirect effect becomes less important, however, and portfolio home bias falls. This accounts for property (b).

[2] In the online supplement I show that in this simple model environment my numerical method replicates this solution exactly for any number of countries.

In the model with intermediate inputs, the size of the indirect financing effect is determined by the composite trade openness parameter $\Omega \equiv D\omega + F(1-\omega)$. The constants D and F represent the amounts of domestic and imported gross output, respectively, needed to accommodate a one-unit increase in domestic absorption. With home bias in both final demand and intermediate usage, the indirect financing effect is positive because $I\Omega$ is greater than one; an increase in relative investment still boosts relative demand for domestic gross output and thus the terms of trade. Moreover, Ω is increasing in both ω and μ, so openness to trade in final goods and openness to trade in intermediate inputs have the same effect on indirect financing.[3] Consequently, both types of trade have the same effect on international portfolio diversification. This accounts for property (c) and explains why increasing the intermediate trade share has little impact on portfolio diversification in the quantitative analysis.

The indirect financing effect also accounts for properties (d) and (e), the complemtarities between country size and trade openness. When I is large — and each country is relatively small — changes in the trade openness parameters, ω and μ, have a larger impact on the term $(I\Omega-1)/(I-1)$ which governs the size of the indirect effect.

3. Quantitative strategy

To measure the effects of changes in the global production structure on international portfolio diversification, I use a quantitative version of the model to construct a mapping between input-output data and equilibrium portfolios. To assess the overall impact of change in the global production structure, I calibrate the model to input-output tables for 1995 and 2011, and then compare equilibrium portfolio diversification in the two calibrations. To assess the effects of changes in different aspects of the global production structure — country size, trade openness, and intermediate input trade — I construct counterfactual input-output tables for 2011 in which only one of these aspects changes.

To make the changes in model portfolios comparable with the data, I calibrate wedges in households' portfolio-choice first-order conditions so that the model matches each region's 1995 level of portfolio diversification. Thus, when calibrated to 1995 input-output data, the model replicates both the global production structure and portfolio diversification for that year. I hold these wedges fixed when using real or counterfactual data for 2011, which allows me to analyze how changes in the global production structure affect international portfolio diversification holding constant other factors that might affect country portfolios. Mukherjee (2015) shows that these wedges can result from cross-country differences in institutions and corporate governance, for example; the residual portfolio diversification growth that the model does not capture could be the result of financial development.

3.1. Quantitative model

The quantitative model has $I = 4$ asymmetric "countries" that correspond to the regions in figure 1 and a more general input-output structure for production and demand.

[3] Ω is increasing in ω because $D > F$. It is increasing in μ because D (F) is increasing (decreasing) in μ.

Gross output production technologies in this version of the model have a nested CES structure:

$$y_i(s^t) = \left\{ \upsilon_i^{\frac{1}{\eta}} \left[z_i(s^t) k_i(s^{t-1})^{\alpha} \ell_i(s^t)^{1-\alpha} \right]^{\frac{\eta-1}{\eta}} + (1-\upsilon_i)^{\frac{1}{\eta}} \left[\sum_{j=1}^{I} \mu_{i,j}^{\frac{1}{\zeta}} m_{i,j}(s^t)^{\frac{\zeta-1}{\zeta}} \right]^{\frac{(\eta-1)\zeta}{\eta(\zeta-1)}} \right\}^{\frac{\eta}{\eta-1}}. \tag{19}$$

υ_i, the share of value added in gross output, and $\mu_{i,j}$, the share of intermediates sourced from country j, vary across countries. η and ζ, the elasticities of subsitution between value added and intermediates and between intermediates from different sources, respectively, are the same across countries.

Consumption and investment are Armington aggregates of domestic and foreign products:

$$c_i(s^t) = \left[\sum_{j=1}^{I} \omega_{i,c,j}^{\frac{1}{\rho}} c_{i,j}(s^t)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}} \tag{20}$$

$$x_i(s^t) = \left[\sum_{j=1}^{I} \omega_{i,x,j}^{\frac{1}{\rho}} x_{i,j}(s^t)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}, \tag{21}$$

Again, the expenditure share parameters, $\omega_{i,c,j}$ and $\omega_{i,x,j}$ differ across countries, while the elasticity of substitition between domestic and foreign final goods, ρ, is not country-specific.

Finally, household preferences take the parametric form:

$$u_i(c_i(s^t), \ell_i(s^t)) = \frac{c_i(s^t)^{1-\gamma}}{1-\gamma} - \left(\frac{\theta_i}{1+\psi} \right) \left(\frac{\ell_i(s^t)}{\Theta_i} \right)^{1+\psi}. \tag{22}$$

The parameters θ_i and Θ_i, which govern disutility from labor supply and labor endowments, differ across countries, while risk aversion and the Frisch elasticity, γ and ψ, do not. Following Tille and van Wincoop (2010), financial frictions distort households' returns from investing in foreign stocks. I model these frictions as wedges in households' portfolio-choice first-order conditions. The first-order condition for country i's choice of country j's stock is

$$\frac{u'(c_i(s^t))}{p_{i,c}(s^t)} = \sum_{s_{t+1} \in S} \pi(s^t, s_{t+1}) \beta \frac{u'(c_i(s^t, s_{t+1}))}{p_{c,i}(s^t, s_{t+1})} R_j(s^t, s_{t+1}) e^{\tau_i \mathbb{1}_{\{i \neq j\}}}, \tag{23}$$

where

$$R_j(s^t, s_{t+1}) = \frac{q_j(s^t, s_{t+1}) + d_j(s^t, s_{t+1})}{q_j(s^t)}, \tag{24}$$

and τ_i is country i's wedge on foreign stock returns.[4] When the model is calibrated to 1995 input-output data, I choose these wedges to match each region's level of international portfolio diversification in that year. When the model is calibrated to real or counterfactual input-output data for 2011, I do not recalibrate the wedges. This allows for direct comparison of changes in portfolio diversification over time between the model and the data.

[4] In section 2 I normalized the price of each country's consumption good to one as in HP. This approach makes applying the Devereux and Sutherland (2011) method cumbersome, however, so in the quantitative model I choose a single numeraire good (the rest of the world's consumption good) instead; $p_{i,c}(s^t)$ denotes the price of country i's consumption relative to the numeraire.

3.2. *Solving for equilibrium portfolios*

To solve for steady-state portfolios in the quantitative model I use the method of Devereux and Sutherland (2011), which involves a combination of first- and second-order approximations to the equilibrium conditions. Below, I briefly describe how to generalize their method to a many-country, many-asset environment like the one that I study in this paper. More details and example programs can be found in the online appendix.

We can combine the first-order conditions for country i's choices of stocks j and I as

$$0 = \sum_{s_{t+1}\in S} \pi(s^t, s_{t+1}) \frac{u'(c_i(s^t, s_{t+1}))}{p_{i,c}(s^t, s_{t+1})} \left(R_j(s^t, s_{t+1}) e^{\tau_i \mathbb{1}_{\{i\neq j\}}} - R_I(s^t, s_{t+1}) e^{\tau_i \mathbb{1}_{\{i\neq I\}}}\right), \ \forall j < I. \tag{25}$$

The non-stochastic steady-state version of equation (25), which implies that all stocks have the same return, is dependent across countries, so non-stochastic steady-state portfolios are indeterminate. A first-order approximation, which implies that all stocks have the same expected return, is also dependent, so portfolios are still indeterminate.[5] A second-order approximation, though, yields an independent set of equations given by

$$\begin{aligned} 0 = \sum_{s_{t+1}\in S} \pi(s^t, s_{t+1}) \Big[& \hat{R}_j(s^t, s_{t+1}) - \hat{R}_I(s^t, s_{t+1}) + \frac{1}{2}\left(\hat{R}_j(s^t, s_{t+1})^2 - \hat{R}_I(s^t, s_{t+1})^2\right) \\ & + \left(-\gamma \hat{c}_i(s^t, s_{t+1}) - \hat{p}_{i,c}(s^t, s_{t+1})\right)\left(\hat{R}_j(s^t, s_{t+1}) - \hat{R}_I(s^t, s_{t+1})\right) + e^{\tau_i \mathbb{1}_{\{i\neq j\}}} - e^{\tau_i \mathbb{1}_{\{i\neq I\}}} \Big], \ \forall j < I, \end{aligned} \tag{26}$$

where hats denote log-deviations from a variable's steady-state value. Combining (26) for countries i and I, we get

$$\begin{aligned} 0 = \sum_{s_{t+1}\in S} \pi(s^t, s_{t+1}) \Big[& \left(-\gamma \hat{c}_i(s^t, s_{t+1}) - \hat{p}_{i,c}(s^t, s_{t+1}) + \gamma \hat{c}_I(s^t, s_{t+1}) + \hat{p}_{c,I}(s^t, s_{t+1})\right) \\ & \times \left(\hat{R}_j(s^t, s_{t+1}) - \hat{R}_I(s^t, s_{t+1})\right) + e^{\tau_i \mathbb{1}_{\{i\neq j\}}} - e^{\tau_i \mathbb{1}_{\{i\neq I\}}} - e^{\tau_I} + 1 \Big], \ \forall j < I. \end{aligned} \tag{27}$$

Steady-state portfolios must satisfy equation (27) for all $i < I$ and all $j < I$. This equation consists solely of product terms (except for the wedges which are parameters), so first-order approximations are sufficient to evaluate this equation to second-order accuracy. Thus, given a candidate solution for steady-state portfolios, we can linearize the non-portfolio variables and equilibrium conditions and check whether equation (27) is satisfied. When $I = 2$, as in Devereux and Sutherland (2011), there is a single equation that must be solved. When $I > 2$, as in this paper, steady-state portfolios solve the system formed by stacking the equation blocks (27) for each country $i < I$. This generalization works for any portfolio choice problem, regardless of the number of agents and assets.

[5] As in Tille and van Wincoop (2010), the wedges, τ_i, are assumed to be second-order so they do not enter zero- and first-order approximations of the equilibrium conditions. Moreover, in a second-order approximation product terms involving the wedges drop out.

3.3. Calibration procedure

My calibration procedure has three steps. First, I assign some parameters like elasticities of substitution to common values in the literature and estimate a joint process for the productivity shocks $z_i(s^t)$. Table 2 lists this first group of parameters, which I hold fixed in all calibrations. Second, I set the remaining parameters so that the model's non-stochastic steady state replicates one of several input-output tables that I describe below. Table 6 lists the parameters in this second group for each of the input-output tables I use in my quantitative analysis. Third, if using 1995 input-output data to calibrate the production parameters I also calibrate the portfolio-choice wedges, τ_i, so that each region's international portfolio diversification in the model matches the 1995 data. The calibrated values of these wedges can also be found in table 2.

3.3.1. Assigned parameters

There are three elasticities of substitution that must be assigned. I set the elasticity of substitution between value added and intermediates, η, to Atalay (2017)'s estimate of 0.05. Kehoe et al. (Forthcoming) show that this value is consistent with the dynamics of the U.S. gross output/GDP ratio. I set the final and intermediate Armington elasticities, ρ and ζ, to one, a standard value in the international macro literature. In my sensitivity analysis, I show that my results are robust to these choices. Other assigned parameters govern capital formation and preferences. I set the depreciation rate, δ, and the capital share, α, to standard values of 0.06 and 0.36, respectively. I set the discount factor, β, to 0.96 so that the steady-state real interest rate is 4% per year. As in HP, I set risk aversion and the Frisch elasticity each to one: $\gamma = \psi = 1$.

3.3.2. Productivity process

I estimate a stochastic process for productivity of the form

$$\begin{bmatrix} \log z_1(s^t) \\ \log z_2(s^t) \\ \log z_3(s^t) \\ \log z_4(s^t) \end{bmatrix} = P \begin{bmatrix} \log z_1(s^{t-1}) \\ \log z_2(s^{t-1}) \\ \log z_3(s^{t-1}) \\ \log z_4(s^{t-1}) \end{bmatrix} + \begin{bmatrix} \epsilon_1(s^t) \\ \epsilon_2(s^t) \\ \epsilon_3(s^t) \\ \epsilon_4(s^t) \end{bmatrix}, \tag{28}$$

where the matrix P governs persistence and spillovers. The innovations, $\epsilon_i(s^t)$, are drawn from a joint normal distribution with variance-covariance matrix Σ. I use the Penn World Tables to calculate region-level TFP series. The goal of the PWT is to construct data on output and other macroeconomic variables that are measured in consistent units across countries, so this data is well-suited to aggregating output and factors of production within each region. The online appendix describes the treatment of the PWT data in more detail. I find that TFP in the EME and ROW regions is somewhat less persistent and substantially more volatile than TFP in the United States and the ADV region. This is consistent with the findings of other studies that estimate TFP processes for a wide range of countries (see, e.g., Bai and Zhang, 2010). I also find substantial spillovers from the United States to the ADV and ROW regions.

3.3.3. Parameters calibrated to input-output data

Given the values of the fixed parameters, I calibrate the remaining parameters (except for the portfolio wedges, τ_i) so that the model's nonstochastic steady state matches one of the benchmark or counterfactual input-output tables described below. My approach is simple: I plug the input-output table data into the model's equilibrium conditions and back out the implied parameter values. Panel (a) of table 3 shows how one can represent all of the model's steady-state quantities in an input-output table. Rows indicate source and columns indicate destination. The last row and column contain gross output and the penultimate row contains value added. Without loss of generality I assume all steady-state prices are one.

First, I calibrate the intermediate expenditure shares, $\mu_{i,j}$. For example, combine country i's first-order conditions for inputs from countries j and k to obtain:

$$\frac{\overline{p}_j}{\overline{p}_k} = 1 = \left(\frac{\mu_{i,j}}{\mu_{i,k}} \frac{\overline{m}_{i,k}}{\overline{m}_{i,j}}\right). \tag{29}$$

Normalizing $\sum_{j=1}^{N} \mu_{i,j} = 1$, we can immediately recover all values of $\mu_{i,j}$. I use a similar procedure to recover the expenditure shares for consumption, $\omega_{i,c,j}$, and investment, $\omega_{i,x,j}$, and the shares of value added in gross output, υ_i. The weights on disutility from labor, θ_i, can be recovered by using steady-state consumption and labor supply in households' intratemporal optimality conditions. Each country's labor endowment, Θ_i, is set to a fraction $1 - \alpha$ of its value added.

3.3.4. *Portfolio wedges*

When using the 1995 input-output data to calibrate the production parameters, I also calibrate the portfolio wedges, τ_i, so that each region's equilibrium international portfolio diversification in the model is the same as in the 1995 data. I assume that each country's wedge is proportional to the autocovariance of its TFP innovation. This ensures that the the wedges are second-order terms that do not affect the equilibrium dynamics of non-portfolio variables and ensures that portfolios are well-behaved (Tille and van Wincoop, 2010). When using 2011 input-output data (real or counterfactual), I do not recalibrate the wedges.

3.4. *Input-output data*

The input-output tables used in my quantitative analysis are based on data from the World Input Output Database (Timmer et al., 2015), henceforth WIOD, which publishes world input-output tables for each year between 1995 and 2011. Each WIOD input-output table reports gross output, value added, intermediate inputs, and final demand for 40 countries and 35 industries. I aggregate all industries into a single production sector and aggregate countries into four regions: the United States (USA); other advanced economies (ADV); emerging economies (EME); and the rest of the world. Table 1 lists the countries in each region.[6] The online appendix contains additional details about the treatment of the input-output data.

[6]The rest of the world represents developing countries that do not yet have quality national input-output data. The WIOD constructs the rest of the world's gross output and final demand by reconciling the national accounts of the 40 countries in the database with total world output and final demand in the UN National Accounts. The rest of the world's intermediate input matrix is constructed by averaging the data for key emerging economies in the database: Brazil, China, India, Indonesia, Mexico, and Russia. Consequently, the rest of the world is similar to the EME region by construction; one can loosely think of it as a second emerging-economy region.

To measure the overall impact of change in the global production structure I calibrate the model to input-output tables for 1995 and 2011, the first and last years available in the WIOD. Trade is unbalanced in the raw WIOD data, however, which poses a challenge for interpreting these data as steady states in the model. In a steady state, the balance of payments implies that a country's net foreign assets are equal to the product of the interest rate and that country's trade deficit. The United States, for example, which runs trade deficits, would have a positive (and very large) net foreign assets position, while emerging economies, which run trade surpluses, would have negative net foreign assets. This is sharply at odds with the data. To solve this problem, I use the RAS procedure (Bacharach, 1965) to construct similar input-output tables in which each region's size, trade openness, and intermediate trade share are the same as in the raw data but each region's aggregate trade is balanced. This procedure is commonly used in input-output analysis to reconcile input-output tables with data on national income accounts and industry output. The U.S. Bureau of Economic Analysis and other national statistical agencies, for example, use RAS to update national input-output tables between benchmark years, and Johnson and Noguera (2016) use a similar method to reconcile input-output tables, national accounts, and trade data from different sources. The online appendix contains a detailed description of the procedure.

Panels (b) and (c) of table 3 show the balanced input-output tables for 1995 and 2011, respectively.[7] In what follows, I refer to them as the 1995 and 2011 benchmarks. Panels (a) and (b) of table 5 list each region's size, trade openness, and intermediate trade share in the two benchmarks, and the first two columns of table 6 list the parameter values that have been calibrated using the benchmark data.

To separate the effects of changes in region size, trade openness, and intermediate trade, I construct counterfactual input-output tables that represent what the global production structure would have looked like in 2011 had only one of these dimensions changed at a time. In each counterfactual, I use the RAS procedure to construct an input-output table that matches the 2011 benchmark data for one of these dimensions but is otherwise similar to the 1995 benchmark. One might ask: why not simply change the parameters that govern, for example, region size while leaving all other parameters fixed at their 1995 values? The drawback of this alternative approach is that other aspects of the global production structure would change endogenously in equilibrium as well. If one were to change labor endowments, which govern region size, but hold all other parameters fixed, trade openness and intermediate trade shares would change endogenously in response. This alternative exercise would not separate the effects of region size on country portfolios from the effects of other aspects of the global production structure. Using the RAS procedure to construct counterfactual input-output data eliminates these general equilibrium effects, allowing me to isolate the effects of region size, trade openness, and intermediate trade one at a time. Table 4 shows the input-output tables that I have constructed for each counterfactual.

3.4.1. Counterfactual 1: changes in country size only

In the first counterfactual, I construct an input-output table that is similar to the 1995 benchmark except that each region's size changes to match the 2011 data. Panel (c) of table 5 shows that

[7] I have lumped consumption and investment into a single "final demand" category to make the tables easier to read. The full tables can be found in the appendix.

while the counterfactual has the same distribution of world GDP as the 2011 benchmark (and this is by construction), in other respects the counterfactual is indeed similar to the 1995 benchmark: trade openness and intermediate trade shares are close to their 1995 values. Column 3 of table 6 lists the calibrated parameters in this counterfactual. The labor endowments, Θ_i, are the same as in the 2011 benchmark because these parameters map directly to each region's size. The labor disutility parameters, θ_i, change as well because each region's consumption grows in proportion to its GDP. The other parameters are similar to their 1995 benchmark values. There are small changes in the Armington share parameters that reflect the general equilibrium effects of changes in labor endowments. If expenditure shares did not change, advanced economies, which shrank, would trade less while emerging economies and the rest of the world, which grew, would trade more.

3.4.2. Counterfactual 2: changes in trade openness only

The second counterfactual is similar to the 1995 benchmark except that each region's trade as a share of world GDP changes to match the 2011 data. Panel (d) of table 5 verifies that while trade openess rises, region size and intermediate trade shares in this counterfactual are similar to the 1995 benchmark data. Column 4 of table 6 lists the calibrated parameters for the second counterfactual. This time, labor endowments and disutilities remain at their 1995 benchmark levels while the expenditure share parameters change. They do not change exactly as in the 2011 benchmark, though; if they did, the counterfactual would not be consistent with the 2011 trade openness data because region size does not change.

3.4.3. Counterfactual 3: changes in intermediate inputs only

In the last counterfactual, each region's size and total trade openness stay fixed at 1995 benchmark levels but each region's intermediate trade share rises to match the 2011 data. The last column of table 6 shows that, as in the second counteractual, labor endowments and disutility parameters stay fixed at 1995 benchmark values while the expenditure share parameters change. This time, the domestic intermediate Armington shares, $\mu_{i,i}$, fall while the imported intermediate shares rise; the reverse happens for consumption and investment Armington shares. Once again, note that the changes in these share parameters incorporate general equilibrium effects of increased intermediate trade and reduced final goods trade.

4. Quantitative results

Having described the quantitative version of the model, the solution method, the calibration process, and the treatment of the input-output data, I now present the results of the analysis. Panel (a) in table 7 lists the observed change in each region's international portfolio diversification between 1995 and 2011 alongside the model predictions in the benchmark and counterfactual exercises.

4.1. Data: observed changes in international portfolio diversification

I measure each region's international portfolio diversification as the GDP-weighted average of the international portfolio diversification levels of the countries that comprise that region. I use the same measure of country-level international portfolio diversification as HP: foreign assets and liabilities as a percent of total country wealth. The online supplement provides further details on these calculations. Figure 1a and the first column of table 7 show how each region's portfolio diversification evolved between 1995 and 2011. As I have discussed above, the asymmetry between advanced and emerging economies is stark: diversification in the United States and other advanced economies rose dramatically, while diversification in the EME and ROW regions rose little or not at all.

There is one complication that arises in comparing the results of the quantitative analysis to these data. The Lane and Milesi-Feretti dataset that I use to compute country-level international portfolio diversification reports multilateral foreign asset and liability positions only—not bilateral positions. Consequently, I cannot distinguish between inter- and intra-regional asset holdings. For example, German foreign assets, which count towards the ADV region's portfolio diversification, likely include assets issued by France, another country in the ADV region, as well as assets issued by non-ADV countries. Thus, my measure of regional international portfolio diversification may be biased upward. It is not possible to ascertain whether this bias has waxed or waned over time. The U.S. data are unbiased, however, and show that the increase in advanced economies' portfolio diversification is not purely an artifact of the data. Moreover, the changes in regional diversification are unbiased as long as the bias in diversification levels has not changed over time, and these changes are the focus of this paper. The model's predicted changes in regional diversification are not sensitive to the initial levels to which the model is calibrated; in an earlier version of the paper which did not include the wedges used to match initial diversification levels, I obtained similar results for each region's change in diversification.

4.2. Benchmark: overall change in the global production structure

The first stage of the quantitative analysis asks: how did overall change in the global production structure affect international portfolio diversification? To answer this question, I compare the change in each region's portfolio diversification between the 1995 and 2011 benchmark calibrations with that region's change in diversification in the data. The change in portflio diversification between the two benchmark calibrations is shown in the second column of panel (a) in table 7.

The results of the benchmark exercise indicate that for advanced economies, changes in the global production structure account for much of the increase in portfolio diversification observed in the data. For the United States, portfolio diversification rises by 7.33 percentage points in the benchmark model, 19.96 percent of the observed increase. For other advanced economies, the model generates an increase of 18.66 percentage points, or 50.67 percent of the observed increase. The model's predictions are also consistent with the small increases in diversification observed in emerging economies and the rest of the world. Both results support the theory advanced in section 2.

The benchmark results also indicate, though, that other factors are also important in explaining patterns of portfolio diversification growth across regions. In advanced economies, particularly the United States, the observed increase in diversification is larger than in the benchmark model. Technological innovations that reduced information asymmetries may be important in explaining residual growth in advanced economies' portfolio diversification (Mondria and Wu, 2010; Dziuda and Mondria, 2012). For the other two regions, particularly the rest of the world, financial frictions and other institutional problems may have contributed to the persistence of home bias (Mukherjee, 2015). In section 5.4 I show that rising trade imbalances may also have contributed to the asymmetry in portfolio diversification growth between advanced and emerging economies.

4.3. Counterfactual 1: changes in size only

The first counterfactual exercise asks: how did changes in region size affect international portfolio diversification? In this exercise, counterfactual model predictions are given by the difference between each region's portfolio diversification in the 1995 benchmark and that region's diversification in the first counterfactual calibration for 2011. The third column of panel (a) in table 7 lists these predictions.

The results of the first counterfactual indicate that changes in the distribution of world output contributed significantly to the asymmetry in portfolio diversification growth between advanced and emerging economies. For the United States and other advanced economies, which shrank in relative size, portfolio diversification rises in the counterfactual. The increase is larger for the ADV region whose share of world GDP fell more. In emerging economies and the rest of the world, whose relative sizes grew, portfolio diversification falls in the counterfactual. In short, holding other aspects of the global production structure fixed, changes in region size are inversely related to changes in portfolio diversification.

4.4. Counterfactual 2: changes in trade openness only

The second counterfactual asks: how did changes in openness to international trade affect portfolio diversification? Counterfactual model predictions in this exercise are constructed in a similar manner as in the first counterfactual. They are listed in the fourth column of panel (a) in table 7.

The results of the second counterfactual show that increased trade openness raised portfolio diversification in all regions. Moreover, regions with larger increases in openness have larger counterfactual increases in diversification. The EME and ROW, whose openness rose most, have the largest counterfactual increases in diversification, while the United States, where openness rose least, has the smallest increase in diversification. As a result, increased openness reduced the asymmetry in portfolio diversification growth between advanced and emerging economies.

The theoretical analysis in section 2 supports these results and provides some additional context. Properties (d) and (e) of Corollary 1.1, in particular, illustrate why increased trade openness has such a large impact on diversification in emerging economies and the rest of the world and such a small impact in the United States. The EME and ROW regions are small relative to the advanced economies, which makes their portfolios sensitive to changes in trade openness. The EME and ROW regions were also smaller in 1995 than they were in 2011; their growth in size in the benchmark exercise mitigates the impact of their growth in openness. For the United States, which is large relative to other regions and shrank between 1995 and 2011, the reverse is true.

4.5. Counterfactual 3: changes in intermediate trade shares only

The third counterfactual asks: how did increased intermediate goods trade affect portfolio diversification? The last column of panel (a) in table 7 lists the results for this exercise.

All four regions have small changes in diversification in this counterfactual, which indicates that the shift towards intermediate goods trade has not significantly affected country portfolios. This is consistent with the theory advanced in section 2, which shows that trade in intermediate goods has a similar impact on portfolios as trade in final goods. In model simulations I have found that the covariance of domestic capital and labor income, which HP show is a key determinant of home bias in country portfolios, differs little between the 1995 benchmark and this counterfactual. These results are supported by recent findings in the international macroeconomics literature that international input-output linkages do not significantly affect international business cycle properties (Arkolakis and Ramanarayanan, 2009; Johnson, 2014b).

4.6. Changes in bilateral portfolio holdings

Thus far, my analysis has focused on the impact of changes in the global production structure on international portfolio diversification. One might also ask: how does the structure of global production affect bilateral portfolio holdings? The United States and other advanced economies, in particular, have become more internationally diversified. Towards which regions' stocks have the United States and other advanced economies reallocated their portfolios? The Lane and Milesi-Ferretti (2007) data and the symmetric theoretical model presented in section 2 do not permit analysis of bilateral portfolio holdings, but we can investigate the predictions of the quantitative model.

Panel (a) of table 9 lists the changes in each region's bilateral portfolio shares in the benchmark exercise. The results show that the decrease in home bias in the United States and other advanced economies comes primarily from a shift towards the EME region's stock. This is due in part to the fact that the EME region grew most rapidly; Baxter and Jermann (1997) and property (a) of Corollary 1.1 suggest that faster-growing countries should receive more foreign equity investment. Advanced economies' reallocation towards EME stock may also be due to the fact that advanced economies' trade with the EME region grew more than their trade with each other and the rest of the world. The EME region, whose home bias did not change much, shifted its portfolio away from USA stock towards ROW stock. Similarly, the ROW region shifted from USA stock towards EME stock. This may be due in part to the fact that the EME and ROW regions' trade with each other grew rapidly while their trade with the United States grew slowly.

Panels (b)–(d) of table 9 list the changes in bilateral portfolio holdings in each of the three counterfactual exercises. Changes in the global production structure account for these results as well. In the first counterfactual, all regions reduce their holdings of shrinking regions' stocks and increase their holdings of growing regions' stocks. In the second counterfactual, changes in bilateral portfolio shares are consistent with changes in bilateral trade: each region reallocates towards the stocks of other regions with which its trade grows most. In the last counterfactual, in which portfolio diversification does not change significantly, bilateral portfolio shares change little as well.

5. Sensitivity analyses

I have conducted a wide range of additional experiments with my quantitative model. My main results about the impact of the global production structure on international portfolio diversification are robust to changes in many of the model's assigned parameters, functional forms, and other assumptions. In this section, I present the results from several sensitivity analyses which provide additional context for my findings. In each analysis below, I recalibrate all model parameters using the procedure described in section 3.3.

5.1. Armington elasticities

The Armington elasticity of subsitution between domestic and imported goods plays a crucial role in determining home bias in country portfolios. In one-good models like that studied by Baxter and Jermann (1997), where domestic goods and imports are perfect substitutes, equilibrium portfolios entail large short positions in domestic assets. By contrast, models with imperfect substitutability like that studied in section 2 of this paper yield the opposite result; HP show that in such models the level of international portfolio diversification is sensitive to the Armington elasticity. Here, I ask: does the Armington elasticity affect the relationship between the global production structure and equilibrium portfolios?

In my theoretical analysis and my baseline quantitative exercises I assumed a unitary Armington elasticity; common values in international macroeconomics range from 0.9 to 2.0. Panel (b) of table 7 repeats the quantitative exercise using a higher Armington elasticity of 1.25 for both intermediate and final goods. Overall, the global production structure has less impact on portfolio diversification in this version of the analysis. In the counterfactuals, size and openness to trade have less impact while intermediate trade has slightly more impact. In panel (c), which uses a lower elasticity of 0.75 for both final and intermediate goods, the results are reversed, and increasing the intermediate share of trade actually lowers diversification (although this effect is once again small). Quantatively, though, the results of both sensitivity analyses are similar to the baseline results.

Little is known about whether Armington elasticities are higher for intermediate goods or for final goods. In order to analyze the sensitivity of my results to the relative Armington elasticity in intermediate trade, I raise or lower the intermediate Armington elasticity, ζ, and change the final Armington elasticity, ρ, in the opposite direction in order to stabilize the aggregate elasticity using the approach suggested by Johnson (2014b). Panel (d) of table 7 lists the results with a higher elasticity for final goods, and panel (e) lists the results with a higher elasticity for intermediate goods. None of the results change much in these analyses. One thing stands out, though: the effect of intermediate trade (counterfactual 3) is minimized when final goods and intermediate goods have the same Armington elasticity. When final goods are more substitutable (panel (d)), increasing the intermediate trade share has a larger impact on portolios than in the baseline analysis. When intermediate goods are more substitutable (panel (e)), increasing the intermediate trade share lowers diversification, but the magnitude of the effect is again larger than in the baseline. This is consistent with the findings of Baqaee and Farhi (2017), who show that Cobb-Douglas technologies minimize the role of intermediate linkages in propagating sectoral — or in this case, regional — shocks.

5.2. Risk aversion

In my theoretical analysis and baseline quantitative results, I assumed that households have log utility. When households are more risk averse, the need to hedge real exchange rate risk creates an additional motive for diversification (Coeurdacier, 2009; van Wincoop and Warnock, 2010; Coeurdacier and Rey, 2013). HP show that risk aversion has a significant impact on the level of home bias in country portfolios in BKK models. Here, I ask: how does risk aversion affect the role of the global production structure in determining international portfolio diversification?

In panel (f) of table 7, I present the results from a version of the quantitative analysis when risk aversion, γ, is set to 2. In this version of the analysis, the overall impact of the global production structure on portfolio diversification is smaller than in the baseline analysis and the asymmetry between advanced and emerging economies disappears. This is because region size has a smaller impact than in the baseline but trade openness still has a significant impact, and the latter is more important for the EME and ROW regions. The difference in results in the first counterfactual suggests that region size may affect the strength of the real exchange rate hedging motive. This may be an interesting avenue for future research.

5.3. Stochastic process

In the theoretical model studied in section 2 the stochastic process for regional productivity does not affect equilibrium portfolios because the competitive equilibrium replicates the efficient allocation for any arbitrary symmetric process. The quantitative model has two features that could make markets incomplete. First, regions are asymmetric. Second, intermediate inputs and value added are imperfect substitutes — in fact, they are almost perfect complements. Both features prevent me from obtaining theoretical proof of financial market completeness and thus could affect equilibrium portfolios. Here, I ask: does the stochastic process for regional productivity matter for equilibrium portfolios in the quantitative model? If so, how does the stochastic process affect the role of the global production structure in determining international portfolio diversification?

Panel (b) of table 8 presents the results from a version of the analysis without productivity spillovers. In this version, I estimate independent stochastic processes for regional productivity of the standard AR(1) form

$$\log z_i(s^t) = \rho_{i,z} \log z_i(s^{t-1}) + \epsilon_i(s^t), \tag{30}$$

where ϵ_i are independently drawn from normal distributions with region-specific variances σ_i^2. The parameters of the estimated independent productivity processes are

$$\rho_{i,z} = \begin{bmatrix} 0.69 & 0.87 & 0.67 & 0.65 \end{bmatrix}, \quad \sigma_i^2 = \begin{bmatrix} 0.00015 & 0.00018 & 0.00046 & 0.00046. \end{bmatrix} \tag{31}$$

These values are similar to the diagonals of the P and Σ matrices that represent the joint productivity process in the baseline model. The results in this version of the analysis are similar to the baseline results, but changes in the global production structure have less impact on diversification in both the benchmark and counterfactual exercises. Thus, the model's stochastic structure does indeed affect equilibrium portfolios. In particular, the correlation between regional productivities observed in the data appears to amplify the effects of the global production structure on portfolio diversification. This suggests that increased international business cycle synchronicity (see, for example, Perri and Quadrini, 2011) may have contributed to the trends depicted in figure 1a.

To investigate why the stochastic structure affects equilibrium portfolios, I conduct two more related sensitivity analyses. In the first, shown in panel (c) of table 8, I set the elasticity of substitution between value added and intermediate inputs, η, to one and use the correlated stochastic process from the baseline model. These results are similar to the baseline results, but different enough to suggest that complementarity between value added and intermediates prevents market completeness in this environment. In panel (d), I set η to one and use the independent productivity processes estimated above. These results are similar, but not equal to, the independent-productivity results in panel (b). This indicates that regional asymmetries also prevent market completeness. I cannot prove these conclusions theoretically, though, so further research is needed on this front.

5.4. *Trade imbalances*

In the baseline analysis I have assumed that each region's steady-state trade balance is zero in the two benchmark input-output tables and in the three counterfactuals. Between 1995 and 2011, however, regional trade balances diverged: advanced economies' trade balances fell while trade balances in emerging economies and the rest of the world rose. This trend represents a fourth way in which the global production structure changed during this period. In this sensitivity analysis, I ask: what is the role of trade imbalances in determining international portfolio diversification?

Panel (a) of table 10 presents the results of a version of the quantitative analysis in which I do not impose balanced trade. In this version of the analysis, I use the raw 1995 and 2011 input-output data without modification. The benchmark exercise in this version of the analysis captures the effects of diverging trade balances as well as changes in region size, trade openness, and intermediate trade. I also include a fourth counterfactual exercise in which I construct an input-output table that matches 2011 trade balances but is otherwise similar to the 1995 benchmark. This counterfactual isolates the effect of trade imbalances on portfolio diversification. In each calibration, I use the steady-state version of the balance of payments conditions to infer steady-state net foreign assets. Each region's steady-state net foreign asset position is set equal to the negative of its trade balance divided by the steady-state interest rate of 4 percent. Thus, regions with trade deficits have positive net foreign asset positions, while regions with trade surpluses have negative positions.

In the unbalanced-trade version of the benchmark exercise, portfolio diversification grows more in advanced economies than in the baseline analysis, rises less in emerging economies, and falls in the rest of the world. In other words, trade imbalances magnify the asymmetry in portfolio diversification growth between advanced and emerging economies. The drop in the rest of the world's diversification is likely due to the fact that this region had a large trade deficit in 1995; this deficit shrank soon after the spate of sudden stop episodes in the late 1990s. In the unbalanced-trade versions of the first three counterfactuals, region size and intermediate trade have similar effects as in the baseline analysis, while trade openness has a larger effect except in the rest of the world. In the new fourth counterfactual exercise, changes in trade balances are positively correlated with changes in diversification. Falling trade balances raised advanced economies' portfolio diversification, while rising trade balances lowered diversification in emerging economies and the rest of the world. The effects of trade imbalances in the fourth counterfactual are of comparable size to the effects of region size and trade openness in the first two counterfactuals.

Incorporating trade imbalances introduces an additional source of asymmetry across regions, so I redo the sensitivity analysis from section 5.3 to investigate whether trade imbalances affect the role of the stochastic process in determining equilibrium portfolios. Panels (b)-(d) of table 10 present the results of the unbalanced-trade versions of the analyses with independent productivities, Cobb-Douglas technologies, and both modifications, respectively. The effect of trade imbalances (the fourth counterfactual) varies substantially across the four versions of the unbalanced-trade analysis, indicating that this additional source of asymmetry indeed amplifies the impact of the stochastic process on equilibrium portfolios.

The results of the unbalanced-trade analyses indicate that diverging trade balances have had a significant impact on international portfolio diversification. Caution should be taken when interpreting these results, however, because steady-state net foreign asset positions implied by the input-output data are inconsistent with regional net foreign asset positions in the data. The United States, for example, which has a trade deficit, has a negative net foreign asset position in the data but a positive one in the model, and this inconsistency worsens as the U.S. trade deficit rises between the 1995 and 2011 benchmark calibrations. More research is needed to understand the link between diverging trade balances and international portfolio diversification.

6. Concluding remarks

Between 1995 and 2011, international portfolio diversification increased dramatically in the United States and other advanced economies but rose little or fell in the rest of the world. In this paper I showed that the global structure of production and absorption plays an important role in explaining this pattern.

First, I used a theoretical model to highlight the roles of country size, trade openness, and trade in intermediate inputs in determining equilibrium country portfolios. This analysis integrated and generalized the findings of Baxter and Jermann (1997) and Heathcote and Perri (2013) about the effects of country size and international trade on international portfolio diversification. For advanced economies, which shrank and became more open to international trade, the theory predicts an increase in diversification. For emerging economies and the rest of the world, growth in size and trade openness have opposing effects on diversification in theory. Put together, these predictions explain the asymmetry in portfolio diversification growth between advanced and emerging economies shown in figure 1a. I also use the theoretical model to derive novel results about the interaction between country size and trade openness and the role of intermediate input trade in determining international portfolio diversification. These results, too, are consistent with the data and provide useful context for my quantitative findings.

Second, I calibrated a more general version of the model to real and counterfactual input-output data to assess the quantitative effects of changes in the global production structure on international portfolio diversification. To solve for equilibrium portfolios numerically I extended the method of Devereux and Sutherland (2011) a multi-country environment. This technical contribution should prove useful in portfolio choice problems in international macroeconomics as well as other fields. The results of the quantitative analysis indicated that overall change in the global production structure accounts for a large fraction of advanced economies' growth in portfolio diversification and explains why diversification in the rest of the world grew little. The counterfactual exercises indicated that changes in country size increased advanced economies' diversification and decreased diversification elsewhere, increased trade opennness raised diversification around the world, and increased intermediate input trade had little impact.

It is important to note that changes in the global production structure do not explain all of the observed growth in international portfolio diversification. For the United States in particular, my model leaves 80 percent of the growth in diversification unaccounted for. This is due in part to the fact that the United States' place in the global production structure changed less than other regions' places. The ADV, EME, and ROW regions changed more in both size and openness to trade, and the benchmark analysis accounts for more of their observed portfolio diversification growth. It is also due, though, to the fact that the only aspect of my calibration that changes between 1995 and 2011 is the global production structure. Further research is needed to assess the importance of other forces that affect portfolio diversification, especially for the United States. Technological progress that improves investors' access to information (Mondria and Wu, 2010; Dziuda and Mondria, 2012) and institutional or regulatory changes that facilitate cross-border equity trade are likely candidates. Another promising avenue of investigation is the rise of U.S.-based multinational corporations — foreign direct investment undertaken by these entities accounts for a large fraction of the United States' foreign assets. For emerging economies and the rest of the world, whose international portfolio diversification has not grown, institutional problems and lack of financial development are likely culprits (Mukherjee, 2015).

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Appendix A. Supplementary material

Supplementary material related to this article can be found online at https://www.economics.utoronto.ca/steinberg/files/portfolios_supplement_14dec2017.zip.

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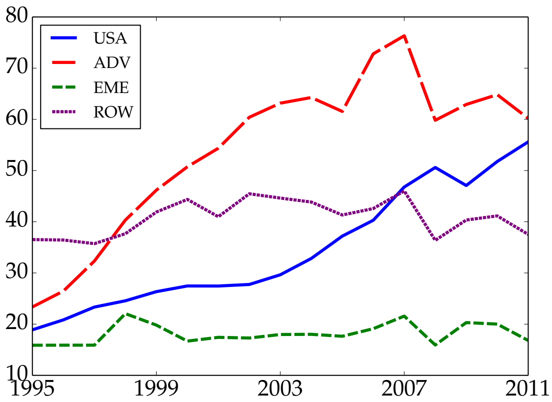
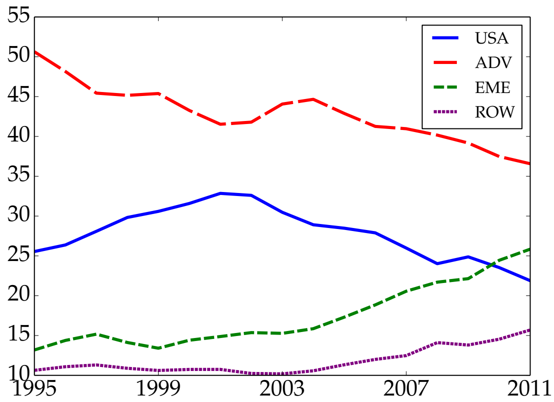
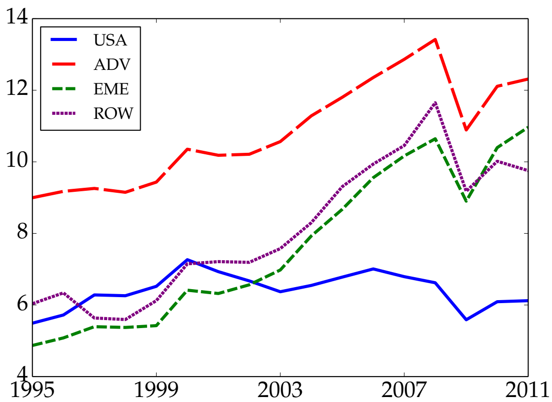


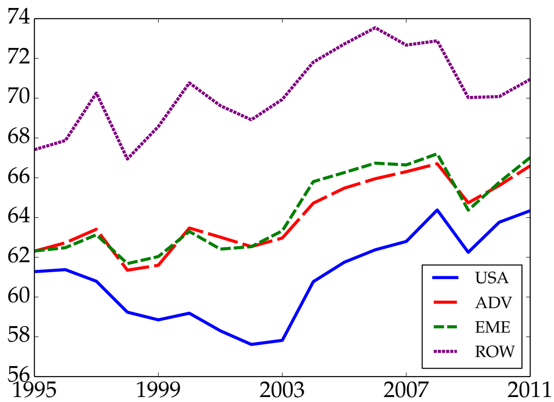
(a) Gross foreign assets (pct. country wealth)



(b) Share of world GDP (pct.)



(c) Imports + exports (pct. world GDP)



(d) Intermediate trade (pct. total trade)

Figure 1: Changes in international portfolio diversification and the global production structure

Table 1: WIOD regional aggregation

Region	Name	Countries
1	USA	USA
2	ADV	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Japan, Ireland, Italy, Luxembourg, Netherlands, Portugal, Sweden, Spain, U.K.
3	EME	Brazil, Bulgaria, China, Cyprus, Czech Republic, Estonia, Hungary, India, Indonesia, Korea, Latvia, Lithuania, Malta, Mexico, Poland, Romania, Russia, Slovakia, Slovenia, Taiwan, Turkey
4	ROW	Rest of the world

Table 2: Parameters fixed across calibrations

Parameter	Value
β	0.96
η	0.05
ζ	1.00
ρ	1.00
δ	0.06
α	0.36
γ	1.00
φ	1.00
τ	$\begin{bmatrix} -0.0000004 & 0.0000011 & -0.0000046 & -0.0000021 \end{bmatrix}$
P	$\begin{bmatrix} 0.69 & -0.02 & -0.10 & 0.00 \\ 0.28 & 0.79 & -0.05 & 0.03 \\ -0.21 & 0.21 & 0.59 & 0.10 \\ 0.23 & -0.10 & -0.10 & 0.63 \end{bmatrix}$
Σ	$\begin{bmatrix} 0.00014 & 0.00007 & 0.00003 & 0.00008 \\ 0.00007 & 0.00016 & 0.00005 & 0.00005 \\ 0.00003 & 0.00005 & 0.00045 & 0.00013 \\ 0.00008 & 0.00005 & 0.00013 & 0.00044 \end{bmatrix}$

Table 3: Input-output representation of model and benchmark input-output tables

	Intermediate inputs				Final demand				
	USA	ADV	EME	ROW	USA	ADV	EME	ROW	GO
(a) Input-output representation of model steady state									
USA	$\bar{m}_{11}$	$\bar{m}_{21}$	$\bar{m}_{31}$	$\bar{m}_{41}$	$\bar{c}_{11} + \bar{x}_{11}$	$\bar{c}_{21} + \bar{x}_{21}$	$\bar{c}_{31} + \bar{x}_{31}$	$\bar{c}_{41} + \bar{x}_{41}$	$\bar{y}_1$
ADV	$\bar{m}_{12}$	$\bar{m}_{22}$	$\bar{m}_{32}$	$\bar{m}_{42}$	$\bar{c}_{12} + \bar{x}_{12}$	$\bar{c}_{22} + \bar{x}_{22}$	$\bar{c}_{32} + \bar{x}_{32}$	$\bar{c}_{42} + \bar{x}_{42}$	$\bar{y}_2$
EME	$\bar{m}_{13}$	$\bar{m}_{23}$	$\bar{m}_{33}$	$\bar{m}_{43}$	$\bar{c}_{13} + \bar{x}_{13}$	$\bar{c}_{23} + \bar{x}_{23}$	$\bar{c}_{33} + \bar{x}_{33}$	$\bar{c}_{43} + \bar{x}_{43}$	$\bar{y}_3$
ROW	$\bar{m}_{14}$	$\bar{m}_{24}$	$\bar{m}_{34}$	$\bar{m}_{44}$	$\bar{c}_{14} + \bar{x}_{14}$	$\bar{c}_{24} + \bar{x}_{24}$	$\bar{c}_{34} + \bar{x}_{34}$	$\bar{c}_{44} + \bar{x}_{44}$	$\bar{y}_4$
VA	$\bar{v}_1$	$\bar{v}_2$	$\bar{v}_3$	$\bar{v}_4$	0.00	0.00	0.00	0.00	$\sum_{i=1}^4 \bar{v}_i$
GO	$\bar{y}_1$	$\bar{y}_2$	$\bar{y}_3$	$\bar{y}_4$	0.00	0.00	0.00	0.00	$\sum_{i=1}^4 \bar{y}_i$
(b) 1995 benchmark									
USA	19.15	0.88	0.35	0.62	24.33	0.52	0.18	0.18	46.21
ADV	0.80	41.73	0.79	1.12	0.63	49.06	0.51	0.61	95.24
EME	0.30	0.83	12.41	0.31	0.32	0.54	12.35	0.14	27.21
ROW	0.41	1.17	0.47	7.91	0.27	0.52	0.15	9.70	20.59
VA	25.55	50.63	13.19	10.63	0.00	0.00	0.00	0.00	100.00
GO	46.21	95.24	27.21	20.59	0.00	0.00	0.00	0.00	189.25
(c) 2011 benchmark									
USA	15.11	0.91	0.66	0.53	20.71	0.45	0.28	0.21	38.86
ADV	0.73	30.84	1.67	1.73	0.45	34.48	0.78	0.78	71.47
EME	0.63	1.69	32.58	1.06	0.51	1.02	24.37	0.56	62.42
ROW	0.51	1.46	1.66	12.89	0.21	0.61	0.42	14.15	31.91
VA	21.89	36.57	25.85	15.70	0.00	0.00	0.00	0.00	100.00
GO	38.86	71.47	62.42	31.91	0.00	0.00	0.00	0.00	204.65

Note: in each panel (b)–(c), all entries are normalized so that world GDP equal to 100.

Table 4: Counterfactual input-output tables

	Intermediate inputs				Final demand				
	USA	ADV	EME	ROW	USA	ADV	EME	ROW	GO
(a) Counterfactual 1: change in relative sizes only									
USA	16.17	0.61	0.45	0.72	20.67	0.40	0.23	0.21	39.47
ADV	0.68	29.61	0.94	1.18	0.49	34.98	0.60	0.64	69.12
EME	0.43	0.99	25.27	0.57	0.42	0.66	24.76	0.25	53.35
ROW	0.42	1.00	0.81	12.23	0.31	0.54	0.26	14.60	30.16
VA	21.89	36.57	25.85	15.70	0.00	0.00	0.00	0.00	100.00
GO	39.59	68.79	53.32	30.40	0.00	0.00	0.00	0.00	192.10
(b) Counterfactual 2: change in openness only									
USA	18.91	0.62	0.62	0.77	24.20	0.41	0.33	0.23	46.08
ADV	0.69	41.02	1.58	1.54	0.48	48.46	1.07	0.84	95.69
EME	0.61	1.67	10.42	1.03	0.56	1.10	11.32	0.46	27.17
ROW	0.45	1.30	1.40	6.61	0.31	0.67	0.47	9.10	20.31
VA	25.55	50.63	13.19	10.63	0.00	0.00	0.00	0.00	100.00
GO	46.21	95.24	27.21	20.59	0.00	0.00	0.00	0.00	189.25
(c) Counterfactual 3: change in intermediate trade shares only									
USA	19.15	0.93	0.37	0.64	24.41	0.46	0.15	0.17	46.29
ADV	0.84	41.73	0.85	1.16	0.59	49.23	0.44	0.57	95.41
EME	0.32	0.89	12.41	0.32	0.30	0.48	12.46	0.13	27.32
ROW	0.42	1.23	0.49	7.91	0.25	0.46	0.13	9.77	20.66
VA	25.55	50.63	13.19	10.63	0.00	0.00	0.00	0.00	100.00
GO	46.29	95.41	27.32	20.66	0.00	0.00	0.00	0.00	189.67

Note: in each panel (a)–(c), all entries are normalized so that world GDP equal to 100.

Table 5: Measures of global production structure in input-output tables

Region	World GDP share (percent)	Total trade (percent world GDP)	Intermediate trade (percent total trade)
(a) 1995 benchmark			
USA	25.55	5.45	61.58
ADV	50.63	8.90	62.76
EME	13.19	4.88	62.55
ROW	10.63	5.97	68.63
(b) 2011 benchmark			
USA	21.89	6.07	65.30
ADV	36.57	12.29	66.64
EME	25.85	10.93	67.34
ROW	15.70	9.75	71.40
(c) Counterfactual 1: change in size only			
USA	21.89	5.38	61.85
ADV	36.57	8.94	62.89
EME	25.85	6.58	63.42
ROW	15.70	7.14	69.24
(d) Counterfactual 2: change in trade openness only			
USA	25.55	6.07	61.84
ADV	50.63	12.29	62.88
EME	13.19	10.93	63.51
ROW	10.63	9.75	69.56
(e) Counterfactual 3: change in intermediate trade share only			
USA	25.55	5.45	64.69
ADV	50.63	8.90	66.30
EME	13.19	4.88	66.51
ROW	10.63	5.97	71.49

Table 6: Parameters that vary across calibrations

			Counterfactuals		
Parameter	1995 Benchmark	2011 Benchmark	1. Size	2. Openness	3. Int. trade
Θ_i	$\begin{bmatrix} 1.92 & 3.80 & 0.99 & 0.80 \end{bmatrix}$	$\begin{bmatrix} 1.92 & 3.21 & 2.27 & 1.38 \end{bmatrix}$	$\begin{bmatrix} 1.92 & 3.21 & 2.27 & 1.38 \end{bmatrix}$	$\begin{bmatrix} 1.92 & 3.80 & 0.99 & 0.80 \end{bmatrix}$	$\begin{bmatrix} 1.92 & 3.80 & 0.99 & 0.80 \end{bmatrix}$
θ_i	$\begin{bmatrix} 3.83 & 1.93 & 7.41 & 9.20 \end{bmatrix}$	$\begin{bmatrix} 3.83 & 2.29 & 3.24 & 5.34 \end{bmatrix}$	$\begin{bmatrix} 3.83 & 2.29 & 3.24 & 5.34 \end{bmatrix}$	$\begin{bmatrix} 3.83 & 1.93 & 7.41 & 9.20 \end{bmatrix}$	$\begin{bmatrix} 3.83 & 1.93 & 7.41 & 9.20 \end{bmatrix}$
υ_i	$\begin{bmatrix} 0.55 & 0.53 & 0.48 & 0.52 \end{bmatrix}$	$\begin{bmatrix} 0.56 & 0.51 & 0.41 & 0.49 \end{bmatrix}$	$\begin{bmatrix} 0.55 & 0.53 & 0.48 & 0.52 \end{bmatrix}$	$\begin{bmatrix} 0.55 & 0.53 & 0.48 & 0.52 \end{bmatrix}$	$\begin{bmatrix} 0.55 & 0.53 & 0.48 & 0.51 \end{bmatrix}$
$\mu_{i,j}$	$\begin{bmatrix} 0.93 & 0.04 & 0.01 & 0.02 \\ 0.02 & 0.94 & 0.02 & 0.03 \\ 0.02 & 0.06 & 0.89 & 0.03 \\ 0.06 & 0.11 & 0.03 & 0.79 \end{bmatrix}$	$\begin{bmatrix} 0.89 & 0.04 & 0.04 & 0.03 \\ 0.03 & 0.88 & 0.05 & 0.04 \\ 0.02 & 0.05 & 0.89 & 0.05 \\ 0.03 & 0.11 & 0.07 & 0.79 \end{bmatrix}$	$\begin{bmatrix} 0.92 & 0.03 & 0.02 & 0.03 \\ 0.02 & 0.91 & 0.03 & 0.04 \\ 0.02 & 0.03 & 0.92 & 0.03 \\ 0.05 & 0.08 & 0.04 & 0.83 \end{bmatrix}$	$\begin{bmatrix} 0.92 & 0.03 & 0.03 & 0.02 \\ 0.02 & 0.91 & 0.04 & 0.03 \\ 0.04 & 0.11 & 0.74 & 0.10 \\ 0.08 & 0.16 & 0.10 & 0.66 \end{bmatrix}$	$\begin{bmatrix} 0.92 & 0.04 & 0.02 & 0.02 \\ 0.02 & 0.93 & 0.02 & 0.03 \\ 0.03 & 0.06 & 0.88 & 0.03 \\ 0.06 & 0.12 & 0.03 & 0.79 \end{bmatrix}$
$\omega_{i,c,j}$	$\begin{bmatrix} 0.97 & 0.01 & 0.01 & 0.01 \\ 0.01 & 0.97 & 0.01 & 0.01 \\ 0.01 & 0.03 & 0.95 & 0.01 \\ 0.01 & 0.04 & 0.01 & 0.94 \end{bmatrix}$	$\begin{bmatrix} 0.97 & 0.01 & 0.01 & 0.01 \\ 0.01 & 0.95 & 0.02 & 0.02 \\ 0.01 & 0.03 & 0.95 & 0.02 \\ 0.01 & 0.05 & 0.03 & 0.91 \end{bmatrix}$	$\begin{bmatrix} 0.96 & 0.01 & 0.02 & 0.01 \\ 0.01 & 0.96 & 0.02 & 0.01 \\ 0.01 & 0.02 & 0.97 & 0.01 \\ 0.01 & 0.03 & 0.01 & 0.95 \end{bmatrix}$	$\begin{bmatrix} 0.97 & 0.01 & 0.02 & 0.01 \\ 0.01 & 0.96 & 0.02 & 0.01 \\ 0.02 & 0.06 & 0.88 & 0.04 \\ 0.02 & 0.05 & 0.03 & 0.90 \end{bmatrix}$	$\begin{bmatrix} 0.97 & 0.01 & 0.01 & 0.01 \\ 0.01 & 0.97 & 0.01 & 0.01 \\ 0.01 & 0.03 & 0.95 & 0.01 \\ 0.01 & 0.04 & 0.01 & 0.94 \end{bmatrix}$
$\omega_{i,x,j}$	$\begin{bmatrix} 0.89 & 0.07 & 0.02 & 0.02 \\ 0.02 & 0.96 & 0.01 & 0.01 \\ 0.02 & 0.07 & 0.90 & 0.01 \\ 0.03 & 0.12 & 0.03 & 0.82 \end{bmatrix}$	$\begin{bmatrix} 0.88 & 0.05 & 0.06 & 0.01 \\ 0.02 & 0.92 & 0.04 & 0.01 \\ 0.01 & 0.04 & 0.93 & 0.02 \\ 0.02 & 0.06 & 0.06 & 0.85 \end{bmatrix}$	$\begin{bmatrix} 0.88 & 0.06 & 0.03 & 0.02 \\ 0.02 & 0.95 & 0.01 & 0.01 \\ 0.02 & 0.04 & 0.93 & 0.01 \\ 0.02 & 0.09 & 0.03 & 0.86 \end{bmatrix}$	$\begin{bmatrix} 0.88 & 0.06 & 0.04 & 0.02 \\ 0.01 & 0.95 & 0.02 & 0.01 \\ 0.04 & 0.15 & 0.77 & 0.03 \\ 0.04 & 0.17 & 0.09 & 0.71 \end{bmatrix}$	$\begin{bmatrix} 0.90 & 0.07 & 0.02 & 0.02 \\ 0.02 & 0.97 & 0.01 & 0.01 \\ 0.02 & 0.06 & 0.91 & 0.01 \\ 0.03 & 0.12 & 0.02 & 0.83 \end{bmatrix}$

Table 7: Changes in diversification: data, baseline model, and sensitivity analyses

Country	Data	Benchmark	Counterfactuals		
			1. Size	2. Openness	3. Int. trade
(a) Baseline					
USA	36.72	7.33	3.23	2.49	0.09
ADV	36.83	18.66	6.22	6.34	0.48
EME	0.93	4.65	-11.36	42.83	0.69
ROW	1.01	0.18	-11.14	32.51	0.45
(b) Higher Armington elasticities					
USA	36.72	2.19	0.20	1.20	0.22
ADV	36.83	10.00	0.29	4.35	0.76
EME	0.93	6.19	-3.61	34.29	1.32
ROW	1.01	0.38	-7.55	32.38	0.92
(c) Lower Armington elasticities					
USA	36.72	8.30	4.33	2.97	-0.61
ADV	36.83	20.87	8.46	6.93	-0.19
EME	0.93	2.72	-14.43	45.70	-0.64
ROW	1.01	-0.83	-12.47	32.46	-0.55
(d) Higher final Armington elasticity					
USA	36.72	8.63	3.24	2.49	1.07
ADV	36.83	20.00	6.23	6.35	1.36
EME	0.93	6.60	-10.95	42.49	2.39
ROW	1.01	1.46	-11.04	32.37	1.73
(e) Higher intermediate Armington elasticity					
USA	36.72	6.42	3.46	2.58	-0.90
ADV	36.83	17.98	6.67	6.45	-0.42
EME	0.93	2.57	-12.36	43.74	-1.06
ROW	1.01	-1.15	-11.51	32.62	-0.88
(f) Higher risk aversion					
USA	36.72	1.21	0.04	1.09	0.12
ADV	36.83	7.11	-0.18	3.26	0.49
EME	0.93	5.12	-2.51	28.37	0.75
ROW	1.01	1.53	-5.85	27.33	0.52

Notes: all results reported above are in percentage points. In panel (b), both Armington elasticities, ρ and ζ, are set to 1.25. In panel (c), both are set to 0.75. In panel (d), the final Armington elasticity, ρ, is set to 1.25 and the intermediate Armington elasticity, ζ, is set to 0.87. In panel (e), ρ is set to 0.75 and ζ is set to 1.14. In panel (f), the risk aversion parameter, γ, is set to 2.

Table 8: Changes in diversification: data, baseline model, and more sensitivity analyses

			Counterfactuals		
Country	Data	Benchmark	1. Size	2. Openness	3. Int. trade
(a) Baseline					
USA	36.72	7.33	3.23	2.49	0.09
ADV	36.83	18.66	6.22	6.34	0.48
EME	0.93	4.65	-11.36	42.83	0.69
ROW	1.01	0.18	-11.14	32.51	0.45
(b) Uncorrelated shocks					
USA	36.72	3.83	2.34	1.52	-0.35
ADV	36.83	10.80	3.66	2.85	-0.03
EME	0.93	0.82	-7.26	20.11	-0.57
ROW	1.01	-2.76	-6.13	14.68	-0.82
(c) Cobb-Douglas production					
USA	36.72	7.24	3.25	2.12	0.04
ADV	36.83	18.89	7.02	7.57	0.46
EME	0.93	3.90	-11.81	44.51	0.68
ROW	1.01	1.18	-11.48	35.39	0.66
(d) Uncorrelated shocks + Cobb-Douglas					
USA	36.72	3.84	2.25	1.54	-0.41
ADV	36.83	9.34	4.17	2.99	-0.14
EME	0.93	-0.51	-7.46	20.24	-0.65
ROW	1.01	-2.46	-5.87	13.90	-0.69

Notes: all results reported above are in percentage points. In panel (b), I use the independent stochastic processes listed in equation (31). In panel (c), I use the baseline stochastic process and set the elasticity of substitution between value added and intermediate inputs, η, to one. In panel (d), I use the independent stochastic processes and set η to one.

Table 9: Changes in bilateral portfolio shares: baseline model

Home\Foreign	USA	ADV	EME	ROW
(a) Benchmark				
USA	-7.33	3.02	3.66	0.65
ADV	3.66	-18.66	9.94	5.05
EME	-4.33	3.42	-4.65	5.56
ROW	-9.68	-1.08	10.94	-0.18
(b) Counterfactual 1: changes in size only				
USA	-3.23	-0.74	1.85	2.12
ADV	-0.79	-6.22	3.42	3.58
EME	-5.40	-5.49	11.36	-0.47
ROW	-3.25	-10.17	2.28	11.14
(c) Counterfactual 2: changes in trade openness only				
USA	-2.49	-2.34	3.45	1.38
ADV	-2.15	-6.34	5.81	2.67
EME	18.33	11.22	-42.83	13.28
ROW	-6.55	21.90	17.16	-32.51
(d) Counterfactual 3: changes in intermediate share share only				
USA	-0.09	0.09	-0.08	0.07
ADV	0.22	-0.48	0.23	0.03
EME	-0.08	0.66	-0.69	0.10
ROW	-0.73	1.25	-0.07	-0.45

Note: all results reported above are in percentage points.

Table 10: Changes in diversification: data and unbalanced-trade calibrations

Country	Data	Benchmark	Counterfactuals			
			1. Size	2. Openness	3. Int. trade	4. Imbalances
(a) Baseline						
USA	36.72	9.73	3.17	2.51	0.02	3.40
ADV	36.83	30.30	6.76	8.16	0.50	11.57
EME	0.93	1.94	-12.32	47.87	0.75	-22.62
ROW	1.01	-17.72	-14.77	14.32	0.14	-26.68
(b) Uncorrelated shocks						
USA	36.72	6.90	2.29	1.71	-0.43	4.96
ADV	36.83	22.86	4.15	3.93	-0.28	14.85
EME	0.93	-3.82	-8.19	22.84	-0.69	-18.39
ROW	1.01	-26.85	-14.15	6.45	-0.80	-23.49
(c) Cobb-Douglas production						
USA	36.72	12.59	3.28	1.79	0.06	5.21
ADV	36.83	27.70	7.99	8.95	0.67	7.01
EME	0.93	-0.75	-12.91	50.12	0.78	-31.15
ROW	1.01	-10.76	-12.67	17.36	0.50	-22.49
(d) Uncorrelated shocks + Cobb-Douglas						
USA	36.72	9.77	2.29	1.31	-0.42	6.93
ADV	36.83	18.38	5.18	3.45	-0.23	10.60
EME	0.93	-7.88	-8.41	22.96	-0.78	-26.90
ROW	1.01	-19.04	-10.87	6.09	-0.58	-16.90

Notes: all results reported above are in percentage points. In all panels, I use the unbalanced input-output tables in the calibration procedure instead of the balanced tables used in the baseline analysis. In panel (a), I use the same assigned parameters as in the baseline analysis. In panel (b), I use the independent stochastic processes listed in equation (31). In panel (c), I set the elasticity of substitution between value added and intermediate inputs, η, to one. In panel (d), I use the independent stochastic processes and set η to one.