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Industrial Specialization Matters: A New Angle on Equity Home Bias

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November 6, 2017

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This paper theoretically and empirically examines how industrial structure affects equity home bias. I embed portfolio choice in a multi-country, multi-sector Eaton-Kortum model in order to explore how sectoral productivity differences affect a country's risk exposure and hence influence home bias. The model predicts that investors from highly specialized economies who want to hedge their risk have a strong incentive to avoid domestic assets. I confirm the prediction with the data by finding that home bias is negatively correlated with a country's degree of industrial specialization. This finding unveils the interaction between intranational risk hedging across sectors and international risk hedging across countries.

KEYWORDS: Home bias, Portfolio choice, Sectoral productivity, Industrial specialization
JEL CLASSIFICATION CODES: F36, F41, G11, G15

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1 Introduction

International finance models typically show that investors can reap substantial benefits from international portfolio diversification. Yet the data indicate that domestic equity accounts for a predominant share of investors' portfolios, despite the current integration of the world capital market. The phenomenon of "equity home bias," documented by French and Poterba (1991) and Tesar and Werner (1995), continues to be a perplexing puzzle in international economics.

Various attempts have been made to examine home bias. Besides informational and institutional frictions that prohibit capital flows, investors' desire to hedge their risk has been proposed as an explanation for why it is optimal to deviate from portfolio diversification.[1] However, most of these studies abstract from industrial structure and as a consequence ignore productivity differences across sectors. In this paper I contend that heterogeneity in sectoral productivity significantly influences the pattern of risk hedging by investors and their portfolio choices. I identify and explain the novel fact that home bias is stronger in countries with more diversified industrial structures.

In order to better understand why industrial specialization may drive the variation in home bias across countries, I build a model in a multi-country, multi-sector dynamic stochastic general equilibrium (DSGE) setting. The model embeds Eaton and Kortum (2002)'s framework to capture the effect of productivity on sectoral size and trade volumes. To obtain an analytical solution to the portfolio choice problem in the baseline two-country, two-sector model, I follow the approach developed by Coeurdacier (2009), who derives investors' optimal asset holdings by analyzing the covariances between asset returns and macroeconomic variables. In solving for equity holdings in an extended

[1] This strand of literature may not necessarily solve the home bias puzzle. For instance, Baxter and Jermann (1997) argue that the puzzle becomes even more difficult once non-diversifiable risks are taken into consideration. See Coeurdacier and Rey (2013) for a detailed discussion.

quantitative framework, I employ the method of Devereux and Sutherland (2007), who use a higher degree of approximation of investors' objective function to capture portfolio behavior.

The solution to the model enriches our understanding of investors' risk-hedging pattern and hence their portfolio choices. In this multi-sectoral setting, investors are able to hedge their risk not only by holding assets in different countries (inter-country risk hedging) but also by holding domestic assets in different sectors (intra-country risk hedging). If the covariance across domestic assets ensures efficient risk hedging, there is less need for investors to hold foreign equities. Thus there is an interesting interaction between the choice of sectors and the choice of countries.

The interaction predicts that industrial specialization has a negative effect on home bias. More industrially-diversified countries exhibit higher degrees of intranational risk hedging such that sectoral shocks in an individual industry do not affect the whole economy in a substantial way. In contrast, highly specialized countries incur greater risks because they have few productive sectors. In those countries there is limited intranational risk hedging since, once the key industries are in peril, other domestic sectors are also susceptible to financial losses. Thus, to hedge their risk, investors hold fewer domestic assets and rely more heavily on international risk hedging by holding foreign assets.

To account for intra- versus inter-national risk hedging patterns, I empirically test the relationship between equity home bias and countries' industrial specialization proxied by the Herfindahl-Hirschman Index (HHI). The home bias index I construct uses proprietary financial datasets, while HHI uses the UNIDO sectoral data. After constructing the two indices, I document a robust negative correlation between them: when institutional features and GDPs are controlled for, a 1 standard deviation increase in HHI is associated with a 0.4 standard deviation decrease in home bias.

In the numerical part of this paper, I extend the baseline model to a quantitative framework that covers a large panel of countries and industries. Employing a method modified from recent trade literature, including Shikher (2011) and Di Giovanni et al. (2014), I estimate sectoral productivity and trade cost consistent with the model and trade data. After that, I solve for investors' portfolio choices given the industrial structure. The model performs well in predicting trade volumes, factor prices, and financial frictions. Furthermore, it replicates the negative correlation between home bias and industrial specialization observed in the data. After evaluating model performance, I simulate a counterfactual scenario absent sectoral productivity differences and find the resulting home bias to be notably higher than in the original case. This result, reflecting the benefit of intranational risk hedging arising from industrial diversification, reinforces the importance of incorporating rich industrial structures in studying equity home bias.

This paper extends the literature that relates investors' risk-hedging motives to equity home bias by adding the sectoral productivity dimension. Coeurdacier and Rey (2013) provide a comprehensive survey of the literature. Baxter and Jermann (1997) argue that home bias is more puzzling when labor income risk — due to the positive correlation between domestic labor and capital income — is taken into account. Cole and Obstfeld (1991), Coeurdacier (2009), and Kollmann (2006) introduce real exchange rate risk by including one tradable good from each country. Unlike previous work, my model allows for multiple sectors of production within countries and intra-sectoral trade across countries. Investors not only choose assets based on the country of issue but also the sector, and thus have more ways to hedge against the two risks. My model is also a more general case of Tesar (1993) and Collard et al. (2007), who have one tradable and one nontradable sector in each country. I introduce trade costs in the quantitative framework to incorporate nontradable sectors. Moreover, this paper is related to the work of Heathcote and Perri (2013) and Steinberg (2017), who link portfolio diversification to trade openness. Unlike their models with taste preference as the main driver of trade, I provide more micro-foundations using a Ricardian multi-sectoral framework. This approach is in line with recent research that examines the macroeconomic implications of trade structure, such as that by Uy et al. (2013) and Eaton et al. (2016).

The analysis in this paper also complements the literature on the interaction of risk sharing and industrial specialization. This strand of literature can be traced back to Helpman and Razin (1978), who argue that the increased benefits of specialization can be achieved by trade in assets to insure against production risk. More recently, Kalemli-Ozcan et al. (2003) and Koren (2003) find empirical support for the positive impact of financial integration on trade specialization. Here I focus on the influence of industrial structure on asset positions by studying how trade specialization affects portfolio diversification. All of these works, which examine the interplay between international goods and capital flows, are particularly important for understanding the patterns of globalization.

The remainder of the paper proceeds as follows: Section 2 describes and solves the baseline model. Section 3 presents the empirical findings. Section 4 conducts the quantitative analysis of an extended framework. Section 5 concludes.

2 Model

In this section I build a two-country, two-sector model in which I solve for optimal portfolios. There are two sectors of different productivity levels in each country. Sectoral sizes and trade patterns are determined by sectoral productivity based on Eaton and Kortum (2002)'s framework. Firms in each country and sector use labor and capital to produce goods. Capital income is distributed to shareholders as a dividend. Households choose portfolios that will maximize their expected lifetime utility. The solution to the portfolio choice problem sheds light on the risk-hedging patterns across sectors and countries.

2.1 Setup

2.1.1 Firms

Two countries ($i = \{H, F\}$) both produce two types of consumption goods ($s = \{a, b\}$). In country i sector s, there is a continuum of varieties $z \in [0, 1]$. The composite good in an industry is a CES aggregate of different varieties with elasticity of substitution ϵ:

$$Y_{i,s} = [\int_0^1 y_{i,s}(z)^{\frac{\epsilon-1}{\epsilon}} dz]^{\frac{\epsilon}{\epsilon-1}}.$$

A firm in country i sector s producing variety z draws its technology $A_{i,s}(z)$ from the Frechet distribution, as in Eaton and Kortum (2002):[2]

$$F_{i,s}(A) = exp(-T_{i,s}A^{-\theta}).$$

$T_{i,s}$ captures the central tendency of sector s in country i: the higher the $T_{i,s}$, the higher the average productivity of the industry. Meanwhile, θ reflects the dispersion of the industry; it takes on a greater value when the sectoral variance is low. Over time, $T_{i,s}$ follows an AR(1) process with autoregressive coefficients $\rho_{i,s}$ and i.i.d. shocks $\epsilon_{i,s,t} \sim N(0, \sigma_\epsilon^2)$:

$$T_{i,s,t} = \rho_{i,s}T_{i,s,t-1} + (1 - \rho_{i,s})\bar{T}_{i,s} + \epsilon_{i,s,t}.$$

Firms use labor and capital to produce goods with a Cobb-Douglas technology. Production factors are mobile within a country but immobile across borders. Given capital

[2] I use Eaton and Kortum (2002)'s framework (EK hereafter) in this paper for two reasons. First, the EK model introduces intra-sectoral trade with minimal parameter restrictions on agents' preference. Second, the EK model has been widely used by economists to examine the macro implications of trade patterns and industrial structures, fitting the purpose of this paper very well. Recent examples in this strand of literature include Eaton et al. (2016) and Alvarez (2017).

share α, production cost c_i is a Cobb-Douglas function of capital rental fee r_i and wage rate w_i: $c_i = r_i^{\alpha} w_i^{1-\alpha}$.[3] Under perfect competition, the price of one unit of variety z in country i sector s is

$$p_{i,s}(z) = \frac{c_i}{A_{i,s}(z)}$$

In this two-country world, consumers choose cheaper goods after comparing domestic and foreign prices. In the baseline case without trade costs, the price consumers pay is

$$p_{i,s}(z) = \min\{p_{H,s}(z), p_{F,s}(z)\}.$$

Aggregating the prices across varieties yields sectoral prices under the Frechet distribution:

$$P_s = [\Gamma(\frac{\theta + 1 - \epsilon}{\theta})]^{\frac{1}{1-\epsilon}} \Phi_s^{-\frac{1}{\theta}} \equiv \gamma \Phi_s^{-\frac{1}{\theta}} \qquad where \qquad \Phi_s = \sum_{i \in \{H,F\}} T_{i,s} c_i^{-\theta}.$$

Consequently, $\pi_{ij,s}$ — the trade share of country j's products in sector s country i — is equal to the probability that the price of country j's goods is lower. Its expression,

$$\pi_{ij,s} = \frac{T_{j,s} c_j^{-\theta}}{\Phi_s},$$

shows that trade share increases in productivity $T_{j,s}$ but decreases in production cost c_j.

Relative productivity across sectors is different across countries. Without loss of generality, I assume country H is more productive in sector a and country F is more productive in b. In the symmetric case, the long-run average productivity satisfies

$$\frac{\bar{T}_{H,a}}{\bar{T}_{H,b}} = \frac{\bar{T}_{F,b}}{\bar{T}_{F,a}} \equiv T > 1,$$

[3] In the baseline case, I assume factor intensity is the same across sectors. This assumption is relaxed in the extended model.

where T captures the productivity disparity between more productive and less productive sectors.

There is an equity market where firms sell their stocks to both domestic and foreign households. Given the Cobb-Douglas production technology, firms use $1-\alpha$ of their revenues to cover labor costs, and pay α as a dividend to stock owners. In other words, dividends are claims to capital income:

$$d_{i,s}(z) = p_{i,s}(z)y_{i,s}(z) - w_{i,s}(z)l_{i,s}(z) = \alpha p_{i,s}(z)y_{i,s}(z).$$

Equities are grouped into four types, each representing an industry of country i sector s: $f_{i,s}$, $(i \in \{H,F\}, s \in \{a,b\})$. The dividends in sector s country i are a constant share of sectoral output:

$$d_{i,s} = \int_0^1 d_{i,s}(z)dz = \int_0^1 \alpha y_{i,s}(z)dz = \alpha Y_{i,s}.$$

Firms hire labor and rent capital for production. In the labor market, a representative household supplies one unit of labor inelastically. Both labor and capital endowments are assumed to be fixed in each country, thus we have market clearing conditions:

$$L_{i,a} + L_{i,b} = L_i, \qquad K_{i,a} + K_{i,b} = K_i.$$

In the symmetric case, endowments are equal across countries: $L_H = L_F$. Another assumption I make in the baseline model is $K_i = \frac{\alpha}{1-\alpha}L_i$. Under this assumption, factor prices are equal to production costs: $r_{i,t} = w_{i,t} = c_{i,t}$. This specification not only simplifies the solution but also makes it comparable to that in other studies of home bias.[4] The solution remains qualitatively the same under alternative assumptions for factor ratios.

[4] For instance, see Coeurdacier and Rey (2013) and Baxter and Jermann (1997).

2.1.2 Households

A representative household in country i has a constant-relative-risk-aversion (CRRA) preference in consumption. Its objective is to maximize the expected lifetime utility defined as

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{C_{i,t}^{1-\sigma}}{1-\sigma}.$$

The household's consumption is a CES bundle of a and b goods.[5] In the symmetric case, I assume that the weight of the more productive sector's goods in consumption is the same across countries.[6] Consumption and aggregate price at home and abroad are given by

$$C_{i,t} = (\psi_i^{\frac{1}{\phi}} C_{i,a,t}^{\frac{\phi-1}{\phi}} + (1-\psi_i)^{\frac{1}{\phi}} C_{i,b,t}^{\frac{\phi-1}{\phi}})^{\frac{\phi}{\phi-1}}, \qquad P_{i,t} = (\psi_i P_{i,a,t}^{1-\phi} + (1-\psi_i) P_{i,b,t}^{1-\phi})^{\frac{1}{1-\phi}},$$

where $\psi_H = 1 - \psi_F = \psi$. Given the CES preference, the optimal expenditure share of country s in sector i is dependent on sectoral prices:

$$\Lambda_{i,s,t} = \lambda_{i,s} (\frac{P_{i,s,t}}{P_{i,t}})^{1-\phi} \quad with \quad \lambda_{H,a} = \lambda_{F,b} = \psi, \qquad \lambda_{H,b} = \lambda_{F,a} = 1-\psi.$$

In the stock market, a household purchases the equities in country i sector s at time t for price $q_{i,s,t}$. Let $\nu_{i,s,t}$ denote the number of shares in country i sector s that a domestic

[5]In the home bias literature, the CES functional form is commonly used but in different contexts. For instance, Coeurdacier (2009) and Kollmann (2006) have a consumption bundle of aggregate domestic and foreign goods. In another strand with multi-sectoral analysis, Tesar and Stockman (1995) and Matsumoto (2007) have a composite of tradables and nontradables. In my framework, the two goods can be a pair of any sectors, whether tradable or not. If there is need to introduce non-tradable sectors, I can introduce high sector-specific trade costs.

[6]The symmetry of preference for sectors simplifies the derivation of closed-form solutions. If $\psi > \frac{1}{2}$, a household consumes more goods in a sector its country is good at producing. With the greater size of the productive sector, I arrive at the usual assumption of consumption home bias commonly seen on the topic; see, e.g. Kollmann (2006) and Heathcote and Perri (2013).

household holds at time t, and $\nu^*_{i,s,t}$ denote the asset holdings of a foreign household. Households' budget constraints state that the sum of consumption expenditures and changes in equity positions is equal to the sum of labor income and dividend income:

$$\begin{aligned} P_{H,t}C_{H,t} + \sum_{s=\{a,b\}} [q_{H,s,t}(\nu_{H,s,t} - \nu_{H,s,t-1}) + q_{F,s,t}(\nu_{F,s,t} - \nu_{F,s,t-1})] \\ = w_{H,t}L_{H,t} + \sum_{s=\{a,b\}} (d_{H,s,t}\nu_{H,s,t} + d_{F,s,t}\nu_{F,s,t}), \end{aligned} \tag{1}$$

$$\begin{aligned} P_{F,t}C_{F,t} + \sum_{s=\{a,b\}} [q_{H,s,t}(\nu^*_{H,s,t} - \nu^*_{H,s,t-1}) + q_{F,s,t}(\nu^*_{F,s,t} - \nu^*_{F,s,t-1})] \\ = w_{F,t}L_{F,t} + \sum_{s=\{a,b\}} (d_{H,s,t}\nu^*_{H,i,t} + d_{F,s,t}\nu^*_{F,s,t}). \end{aligned} \tag{2}$$

In this two-country context, the complete market features perfect risk sharing across countries such that an individual country's consumption is not subject only to its own income constraint. According to Backus and Smith (1993), the optimal consumption allocation in the complete market satisfies

$$\frac{U'(C_{H,t})}{U'(C_{F,t})} = \frac{P_{H,t}}{P_{F,t}} = e_t.$$

In words, the relative marginal utility across countries equals the consumption-based real exchange rate. This allocation coincides with the decision of a social planner who assigns equal weights to representative households in each country. The solution to the portfolio choice problem will support this optimal allocation.

2.1.3 Equilibrium

The equilibrium of the model consists of a sequence of prices such as goods prices $P_{i,s,t}, P_{i,t}, P_{s,t}$, wages $w_{H,t}, w_{F,t}$, asset prices $q_{i,s,t}$, dividends $d_{i,s,t}$, and the real exchange rate e_t, as well as a vector of quantities including output $Y_{i,s,t}$, consumption $C_{i,s,t}, C_{i,t}$, labor $L_{i,s,t}$, capital $K_{i,s,t}$, and asset holdings $\nu_{i,s,t}$ such that:

(a) Firms choose prices and quantities to maximize their profits;

(b) Households choose consumption and equity holdings to maximize expected lifetime utility;

(c) Goods markets clear: $\sum_{i=\{H,F\}} Y_{i,s,t} = \sum_{i=\{H,F\}} C_{i,s,t}$;

(d) Factor markets clear: $\sum_{s=\{a,b\}} L_{i,s,t} = L_i$, $\sum_{s=\{a,b\}} K_{i,s,t} = K_i$;

(e) Equity markets clear: $\nu_{i,s,t} + \nu^*_{i,s,t} = 1$ each $f_{i,s}, (i \in \{H, F\}, s \in \{a, b\})$.

(f) Portfolio holdings support the optimal consumption allocation in the complete market.

2.2 Portfolio Choice

In order to solve for the portfolio choices in the model, I apply and extend Coeurdacier and Rey (2013)'s analysis to a case with multiple sectors in a country. To do so, I log-linearize the model around the steady state (see Appendix B.1) and derive the portfolio that supports the optimal consumption allocation regardless of the types of productivity shocks realized in the economy. I start with the partial equilibrium where I relate portfolio choices to variables' covariances and then proceed to the general equilibrium where the portfolio is expressed in terms of parameters in the model.

There are four types of equities in a domestic household portfolios and three unknown weights: the weight of sector a in the portfolio μ and the weights of domestic assets within each sector S_a, S_b. Thus, the weights of the four assets $f_{H,a}, f_{H,b}, f_{F,a}$, and $f_{F,b}$ are $\mu S_a, \mu(1 - S_a), (1 - \mu)S_b$, and $(1 - \mu)(1 - S_b)$ respectively. Given the symmetry across countries, foreign asset holdings should be the mirror image of domestic asset holdings: $S_a = S^*_b, S_b = S^*_a, \mu^* = 1-\mu$ (asterisk is shorthand for foreign investors' portfolio weights).

Plugging this result in the static budget constraints of the two countries yields

$$P_H C_H = w_H L_H + \mu S_a d_{H,a} + \mu(1 - S_a) d_{F,a} + (1 - \mu) S_b d_{H,b} + (1 - \mu)(1 - S_b) d_{F,b}, \quad (3)$$

$$P_F C_F = w_F L_F + \mu S_a d_{F,b} + \mu(1 - S_a) d_{H,b} + (1 - \mu) S_b d_{F,a} + (1 - \mu)(1 - S_b) d_{H,a}. \quad (4)$$

I examine the country's home bias by adding up the two budget constraints (equation 3 and 4). Let $\chi(x_1, x_2)$ be the covariance between variable x_1 and variable x_2 and $\chi^2(x)$ be the variance of variable x. I also denote the sum of the covariances of variable $\hat{x}$ with $\hat{d}_a, \hat{d}_a$ as $\sum \chi(\hat{x})$ and the variance of sectoral relative returns as $\chi^2 = \chi^2(\hat{d}_a) = \chi^2(\hat{d}_b)$.

Proposition 1. *The share of domestic assets in the portfolio is*

$$\begin{aligned} \mu S_a + (1 - \mu) S_b = \frac{1}{2} + [\frac{\sigma - 1}{2\sigma\alpha} \sum \chi(\hat{e}) - \frac{1 - \alpha}{2\alpha} \sum \chi(\hat{wL}) - \frac{2\mu - 1}{2} \sum \chi(\hat{d}_H)] \\ \times [\chi^2 + \chi(\hat{d}_a, \hat{d}_b)]^{-1}. \end{aligned} \quad (5)$$

When the households are risk averse, they increase their aggregate foreign holdings to hedge against labor income risk, and increase their aggregate domestic holdings to hedge against real exchange rate risk.

Proof. See Appendix B. □

In equation 5, aggregate domestic share (denoted as D hereafter) consists of four terms: $\frac{1}{2}$, $\sum \chi(\hat{e})$, $\sum \chi(\hat{wL})$ and $\sum \chi(\hat{d}_H)$. $\frac{1}{2}$ represents households' diversification motives across countries. If there is no covariance between asset returns and macro variables, a household splits its portfolio evenly across the two countries' assets (as in Lucas (1982)). The other three terms capture households' asset positions driven by risk-hedging incentives. With $\chi^2 + \chi(\hat{d}_a, \hat{d}_b) > 0$, aggregate domestic share D increases in $\sum \chi(\hat{e})$ when $\sigma > 1$, meaning that risk-averse households buy domestic assets to hedge against real exchange rate risk. The intuition is that when households are risk averse they have a greater need to smooth consumption across time. In order to stabilize their purchasing power, they prefer to hold assets whose returns are high when local goods are expensive. As a result, they hold domestic assets since there is a positive correlation between domestic returns and local prices. Besides, D also decreases in $\sum \chi(\hat{wL})$, indicating that households hold foreign assets to hedge against domestic labor income risk. This result stems from the positive correlation between domestic labor income and domestic asset returns. So far, the conclusions resonate with those in prior works summarized in a generic form by Coeurdacier and Rey (2013).

What is new in my analysis is the term capturing the covariance between domestic returns across sectors $\sum \chi(\hat{d}_H)$. Its sign determines the relationship between the choice of sectors and the choice of countries.

Proposition 2. *Sectoral share μ and national share D are substitutes as long as $\sum \chi(\hat{d}_H) > 0$. If $\sum \chi(\hat{d}_H) < 0$, μ and D are complements.*

The reasoning is as follows. $\hat{d}_H$ is the increase of $d_{H,a}$ relative to $d_{H,b}$. When $\sum \chi(\hat{d}_H)$ is positive, domestic relative to foreign returns is increasing in sectoral returns of the more productive sector relative to the less unproductive sector. Algebraically,

$$\begin{aligned}\sum \chi(\hat{d}_H) &= \chi(\hat{d}_H, \hat{d}_a) + \chi(\hat{d}_H, \hat{d}_b) \\ &= \chi(\hat{d}_{H,a} - \hat{d}_{H,b}, \hat{d}_{H,a} - \hat{d}_{F,a}) + \chi(\hat{d}_{H,a} - \hat{d}_{H,b}, \hat{d}_{H,b} - \hat{d}_{F,b}) > 0.\end{aligned} \tag{6}$$

When the intranational gap $(\hat{d}_{H,a} - \hat{d}_{H,b})$ widens, so does the international gap $(\hat{d}_{H,s} - \hat{d}_{F,s}, s = a, b)$. In this situation, $f_{H,a}$ the productive sector at home is associated with great risks, so aggregate domestic holdings D decrease in aggregate productive sectors' holdings μ; Households skew their choice toward foreign assets to globally diversify the risks associated with favoring the productive sector. In the other case where $\sum \chi(\hat{d}_H) < 0$, intranational risk and international risk partially cancel out. For example, the improved performance of the productive sector at home lowers the relative performance of the home country as a whole. The negative correlation makes domestic assets a good hedge against the risks associated with the productive sector. Therefore, aggregate domestic holdings $D(=\nu_{H,a}+\nu_{H,b})$ increase with sectoral holdings of the productive sector $\mu(=\nu_{H,a}+\nu_{F,b})$. Nonetheless, this case is rare both theoretically and empirically.

Adding this interplay between sector and country choices points to a new explanation for why home bias in some countries is strong. In an economy with $\sum\chi(\hat{d}_H) > 0$, D takes a higher value when μ is low. Intuitively, in order to shield themselves from the excessive risks associated with domestic productive sectors, investors hold either domestic assets in unproductive sectors or foreign assets. The former is intranational risk hedging across sectors and the latter is international risk hedging across countries. If investors hold many unproductive sectors' assets, intranational risk hedging across sectors replaces the need for international risk hedging across countries. Therefore the country exhibits strong home bias.

Next I analyze the general equilibrium of the model. Households choose portfolio weights μ, S_a, and S_b regardless of the type of shocks to be realized in the economy. Thus I solve the portfolio problem by matching the corresponding coefficients of productivity shocks.

Proposition 3. *In this complete market, asset holdings in the general equilibrium features*

$$\Omega_1 \equiv \mu S_a - (1-\mu)(1-S_b) = -\frac{T}{T+1}\frac{1-\alpha}{\alpha} + \frac{T}{T+1}\frac{1}{\alpha}\frac{(1-\frac{1}{\sigma})}{\lambda-\theta}, \tag{7}$$

$$\Omega_2 \equiv (1-\mu)S_b - \mu(1-S_a) = \underbrace{-\frac{1}{T+1}\frac{1-\alpha}{\alpha}}_{\textit{Labor Income Risk}} \underbrace{-\frac{1}{T+1}\frac{1}{\alpha}\frac{(1-\frac{1}{\sigma})}{\lambda-\theta}}_{\textit{Exchange Rate Risk}}, \tag{8}$$

where $\lambda \equiv 1+\theta-\phi+(2\psi-1)^2(\phi-\frac{1}{\sigma})$.

Proof. See Appendix B. □

In the expressions above, Ω_1 reflects the difference in investors' holdings of domestic and foreign productive sectors, while Ω_2 reflects the difference in investors' holdings of domestic and foreign unproductive sectors. The term $-\frac{1-\alpha}{\alpha}$ captures households' hedging against labor income risk. When we add the coefficients before the term across Ω_1 and Ω_2, we have $\frac{T}{T+1} + \frac{1}{T+1} = 1$. This result, that the sum is a fixed number, indicates that, if investors hold many domestic productive sectors' assets ($f_{H,a}$ in the example), fewer domestic unproductive sectors' assets ($f_{H,b}$) are needed to hedge labor income risk. Similarly, $\frac{1}{\alpha}\frac{(1-\frac{1}{\sigma})}{\lambda-\theta}$ captures the hedging against real exchange rate risk. When we take the difference between the coefficients before the term across Ω_1 and Ω_2, we have $\frac{T}{T+1} - (-\frac{1}{T+1}) = 1$. This suggests that, if investors hold many domestic productive sectors' assets ($f_{H,a}$), they also need to hold more domestic unproductive sectors' assets ($f_{H,b}$) to hedge exchange rate risk. According to this analysis, the two sectors within a country achieve intranational risk hedging by (1) alleviating the positive correlation between labor income and the performance of the other sector and (2) stabilizing the real exchange rate such that the country's purchasing power is not excessively subject to price fluctuations in the other sector. This analysis of the interaction between sectors within a country provides a more robust understanding of countries' risk-hedging patterns than the one-sector case discussed in previous literature.

Adding up equations 7 and 8 yields aggregate domestic shares

$$D = \frac{1}{2} - \frac{1}{2}\frac{1-\alpha}{\alpha} + \frac{1}{2}\frac{1}{\alpha}\frac{T-1}{T+1}\frac{1-\frac{1}{\sigma}}{\lambda-\theta}. \tag{9}$$

Equation 9 in the general equilibrium is the counterpart to equation 5 in the partial equilibrium. The first term $\frac{1}{2}$ is the diversification term, the second term captures the hedging of labor income risk, and the third term reflects the hedging of real exchange rate risk. Based on domestic shares, home bias is

$$HB = 1 - \frac{1-D}{1/2} = -\frac{1-\alpha}{\alpha} + \frac{1}{\alpha}\frac{T-1}{T+1}\frac{1-\frac{1}{\sigma}}{\lambda-\theta}. \tag{10}$$

Equation 10 is comparable to the theoretical results in several previous papers on the topic. When $T = 1$, we are back to Baxter and Jermann (1997)'s case in the absence of real exchange rate risk, where sectors' influence on exchange rates is ignored. When $T = \infty$, as in Coeurdacier (2009)'s case, there is full specialization and no intra-sectoral trade. Between these two extreme cases, we draw the following conclusion:[7]

Proposition 4. *Home bias decreases in T, the productivity difference between sectors.*

This proposition can be understood by considering the intra- versus inter-national risk-hedging mechanism discussed earlier. When there is much productivity disparity between sectors, world production and trade are more specialized. In this circumstance, domestic unproductive sectors' assets are highly correlated with productive sectors' since the two sectors share the same local production costs. When domestic asset returns are highly correlated across sectors, there is limited intranational risk hedging, which in turn induces households to hold more foreign assets for inter-national risk-hedging.

Proposition 4 predicts that countries with diversified industrial structures show stronger home bias than countries with few major industries. I confront this theory with data in the next section.

[7] The proposition holds as long as $\lambda < \theta$. This happens when the elasticity of substitution between tradable sectors is above unity. The literature, including Levchenko and Zhang (2014), estimates the parameter to be 2.

3 Empirical Analysis

In this section, I empirically examine the relationship between industrial specialization and equity home bias. I use Factset/Lionshare and Datastream to construct the home bias index and UNIDO to calculate the Herfindahl-Hirschman index (HHI) as a measure of countries' industrial specialization.

3.1 Data

Coeurdacier and Rey (2013) define home bias as the difference between the actual country-level holdings of equities and the share of market capitalization in the global equity market to measure home bias. Home bias in country i equals

$$HB_i = 1 - \frac{\text{Share of Foreign Equities in Country i Equity Holdings}}{\text{Share of Foreign Equities in the World Market Portfolio}}. \tag{11}$$

$HB_i = 1$ indicates that country i is fully home biased since it does not hold any foreign equities. $HB_i = 0$ indicates that country i is fully diversified between domestic and foreign equities. In theory, HB_i can take any value below 1 (including a negative value).[8]

To construct the home bias index, I use proprietary financial datasets. The numerator in the expression for HB_i uses data from Factset/Lionshare. This dataset provides comprehensive information on the equity holdings of institutional investors from a large number of countries or regions since 1998. The denominator in equation 11 uses data from Datastream. Thomson Reuters Datastream offers global financial data including

[8]Home bias is negative when investors outweigh foreign assets relative to market capitalization. Home bias is smaller than 1 since all the equity holdings are positive in the data. In a model without short-sale constraints, equity holdings can be negative and home bias is no longer bound by 1.

market values, with which I obtain countries' weights in the world equity market. Figure A.1 shows that the home bias index constructed in this paper lines up well with that in previous studies that use macro data. For further details on the datasets, refer to Hu (2017).

Table A.1 lists the constructed home bias index. The mean is 0.56 and the standard deviation is 0.31. Small open economies like Norway, the Netherlands, and Austria show the weakest preference for domestic equities, close to the full diversification scenario with zero home bias. In contrast, Romania, China, and Russia show almost full home bias, due to either stringent capital controls or, my focus, hedging motives. I control for the former while exploring the latter in regression analyses.

In terms of the explanatory variable for home bias, I use the Herfindahl-Hirschman index (HHI) as a proxy for countries' degree of industrial specialization. HHI in country i is defined as the sum of squared shares of each sector (s) in the country's total output:

$$HHI_i = \sum_{s=1}^{S} b_{i,s}^2.$$

The greater the HHI value, the more concentrated the country's production. I use the ISIC Rev.4 sectoral value-added data from UNIDO to calculate countries' HHI.[9] Among all the countries, exporters of natural resources such as Kuwait and Qatar exhibit the highest HHI. In contrast, countries with diversified industrial structures, like Australia and the United States, exhibit low HHI values.

Besides industrial specialization measured by HHI, I also consider other variables that potentially influence home bias. To control for the size of economies, I use real GDP data from the World Bank to calculate average values between 1998 and 2014, the same period that the home bias data cover. Moreover, transaction barriers such as capital controls

[9] Industries are aggregated to two-digit ISIC levels, including 15 manufacturing sectors, consistent with the numerical analysis.

also affect investors' international diversification. To this end, I add an OECD dummy as a control variable to my analysis to see whether developed economies with fewer institutional frictions depict weaker home bias. In robustness checks (Table A.2), I also consider the Chinn-Ito index as a measure of financial openness. Chinn and Ito (2006) use the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER) to compile this de-jure measure of capital account openness, which has become widely used in the international finance literature.

3.2 Findings

Table 1: Home Bias and Industrial Specialization

Dep. Var: Home Bias	(1)	(2)	(3)	(4) Excluding oil exporters
HHI	-0.947 *	-2.370 ***	-2.370 ***	-5.485 **
	(0.525)	(0.680)	(0.838)	(2.792)
	[-0.162]	[-0.406]	[-0.402]	[-0.419]
OECD		-0.312 ***	-0.302 ***	-0.323 ***
		(0.102)	(0.105)	(0.106)
		[-1.020]	[-0.982]	[-1.044]
log(GDP)			0.016	0.011
			(0.073)	(0.067)
			[0.029]	[0.020]
Constant	0.606 ***	0.913 ***	0.716	0.963
	(0.068)	(0.099)	(0.910)	(0.885)
Observations	37	37	36	33
R^2	0.026	0.201	0.197	0.241

Note: Robust standard errors in parentheses and standardized coefficients in brackets. *significant at 10%, **significant at 5%, and ***significant at 1%. The dependent variable is home bias. The independent variables include Herfindahl-Hirschman Index (HHI), OECD dummy, and real GDP in natural logs.

The regression results are summarized in Table 1. In column (1), when a country's HHI increases by 1 standard deviation, home bias decreases by 0.162 standard deviation. In column (2), I add a dummy for OECD countries, taking into account the fact that institutional features of financial markets are different between developing and developed countries. I find that OECD countries depict weaker home bias by around 1 standard deviation. After adding this measure of financial openness, the coefficient of HHI increases in absolute value, which indicates that specialization becomes more important in explaining the variation in home bias. In column (3) where I add the size of the economies (proxied by GDP) as another control variable, the result is similar. The coefficient of HHI is negative at the 1 percent level of significance in both cases. When a country's HHI increases by 1 standard deviation, home bias decreases by about 0.4 standard deviation. Besides, GDP is not significantly related to home bias, similar to the finding in Heathcote and Perri (2013).

Figure A.2 plots home bias against industrial specialization. Countries such as Qatar and Kuwait, which are heavily dependent on the oil industry as their main source of income, have great HHI_i. Because their economies rely heavily on natural resources, other sectors in these countries cannot provide a buffer when the oil industries fluctuate. Hence the limited domestic options prompt their investors to invest abroad for international risk hedging. In contrast, Australia and the United States have highly diversified industrial structures, so they can benefit from high degrees of intranational risk hedging, which replaces the need for investors to hedge their risk by holding foreign assets. As a result, home bias in these two economies is relatively strong.

In column (4) of Table 1, I exclude the three outliers, Kuwait, Norway, and Qatar, for fear that portfolio strategies specific to these oil exporters may bias the result. The result is robust as the coefficient of HHI is still significantly negative and the slope becomes steeper, indicating that industrial structure plays an important role in explaining the variation in home bias among non oil-exporters.

To sum up this section, I use proprietary financial datasets to compute home bias and find its negative correlation with industrial specialization. This novel empirical finding, which is not explained in the existing literature, underscores the importance of a multi-sectoral framework for studying home bias. In the next section, I implement a quantitative assessment of an extended model.

4 Quantitative Assessment

In this section I conduct a numerical analysis of the model in order to further examine the influence of industrial structure on portfolio diversification. I first extend the baseline two-country, two-sector framework used in Section 2 to a case with a large panel of countries and industries. I then estimate sectoral productivity and trade costs consistent with the model using national and sectoral trade data. After that, I solve for investors' optimal asset holdings given countries' industrial structures. Finally, I run a counterfactual exercise to compute home bias in the case when sectoral productivity differences are absent.

4.1 Extended Model

The extended model features I countries and $S+1$ industries. Consumption in country $i \in \{1, 2, ..., I\}$ is a Cobb-Douglas bundle of S tradable sectors and one nontradable sector denoted as N:

$$C_i = C_{i,T}^{\mu_i} C_{i,N}^{1-\mu_i} = (\sum_{s=1}^{S} \psi_s^{\frac{1}{\phi}} C_{i,s}^{\frac{\phi-1}{\phi}})^{\frac{\phi}{\phi-1}\mu_i} C_{i,N}^{1-\mu_i}.$$

μ_i denotes the weight of the tradable bundle ($C_{i,T}$) in country i's consumption. The implied elasticity of substitution between the tradables and nontradables is 1, which falls within the normal range in previous studies.[10] The tradable bundle is a CES composite of consumption in different sectors ($C_{i,s}$), with ψ_s being the weight assigned to sector

[10]The values for the elasticity of substitution between tradable and non-tradable goods range from 0.4 in Tesar and Stockman (1995) to 1.6 in Ostry and Reinhart (1992).

$s \in \{1, 2, ..., S\}$ and ϕ being the elasticity of substitution between sectors within the tradable bundle.

For tradable sectors, iceberg costs τ_i are introduced to the original model to reflect tariffs and other forms of trade barriers when country i exports to and imports from the rest of the world. The past several decades have witnessed significant reductions in trade barriers, which have reshaped industrial structures. Given trade cost τ_i, the price of variety z in sector s exported from country i to the rest of the world becomes $p_{i,s}(z) = \frac{\tau_i c_{i,s}}{A_{i,s}(z)}$.

Aggregating the varieties gives the share of country i's exports in the world market for sector s as

$$\pi_{i,s} = \frac{T_{i,s}(\tau_i c_{i,s})^{-\theta}}{\Phi_s} \qquad where \qquad \Phi_s = \sum_i^I T_{i,s}(\tau_i c_{i,s})^{-\theta}.$$

Meanwhile, the price level of sector s in country i is given by

$$P_{i,s} = [\Gamma(\frac{\theta + 1 - \epsilon}{\theta})]^{\frac{1}{1-\epsilon}} \Phi_{i,s}^{-\frac{1}{\theta}} \qquad where \qquad \Phi_{i,s} = \Phi_s - T_{i,s}(\tau_i^{-\theta} - 1)c_{i,s}^{-\theta}.$$

The price of the nontradable sector $P_{i,N}$ is obtained in a similar way when foreign competitors' trade cost is assumed to go to infinity:

$$P_{i,N} = \Gamma(\frac{\theta + 1 - \epsilon}{\theta})]^{\frac{1}{1-\epsilon}} T_{i,N}^{-\frac{1}{\theta}} c_{i,N}.$$

Production cost in each sector ($c_{i,k}, k \in \{1, 2, ..., S, N\}$) is jointly determined by sector-specific factor intensity α_k and country-specific factor prices including wage and capital rental fee: $c_{i,k} = r_i^{\alpha_k} w_i^{1-\alpha_k}$. As in the baseline model, labor and capital are mobile across sectors but immobile across countries. Factor prices are pinned down by the market-clearing conditions:

$$\sum_{k\in\{1,2,...,S,N\}} L_{i,k,t} = L_{i,t}, \qquad \sum_{k\in\{1,2,...,S,N\}} K_{i,k,t} = K_{i,t}.$$

In the equity market, there are $I \times (S+1)$ types of stocks, each representing $f_{i,k},\ k \in \{1, 2, ..., S, N\}, i \in \{1, 2, ..., I\}$. When I analyze country i, I do not distinguish its specific destinations of foreign investment but group the rest of the world as country F. After all, home bias focuses only on investment decisions related to domestic and foreign equities. Households in country i choose the optimal portfolio to maximize their expected lifetime utility subject to the budget constraint

$$\begin{aligned} &P_{i,t}C_{i,t} + \sum_{j\in\{i_H,i_F\}} \sum_{k\in\{1,2,...,S,N\}} q_{j,k,t}(\nu^i_{j,k,t} - \nu^i_{j,k,t-1}) \\ &= w_{i,t}L_{i,t} + \sum_{j\in\{i_H,i_F\}} \sum_{k\in\{1,2,...,S,N\}} d_{j,k,t}\nu^i_{j,k,t}. \end{aligned} \tag{12}$$

$\nu^i_{j,s,t}$ denotes the number of shares country i holds of sector k from country j at time t. $q_{j,k,t}$ and $d_{j,k,t}$ are asset prices and dividends respectively. As in the baseline model, dividends are claims to capital income: $d_{j,k,t} = \alpha_k p_{j,k,t} y_{j,k,t}$.

Lastly, the aggregate expenditure in country i is given by

$$P_{i,t}C_{i,t} = w_{i,t}L_{i,t} + r_{i,t}K_{i,t}.$$

under the assumption of balanced trade for each country. This assumption ensures that the foreign asset holdings are driven by risk-hedging motives instead of by global imbalances.[11]

[11] Since the sum of a country's current account and capital account is always zero, any trade surplus must be matched by a deficit in the capital account. This channel, which also drives financial flows across borders for countries like China, is important but not the focus of this paper. This paper focuses on the implications of industrial composition for foreign investment.

4.2 Computation

The quantitative exercise covers 15 two-digit ISIC tradable sectors in 58 countries, which account for more than 90 percent of world trade volume. To numerically implement the model, I need to calibrate four categories of model parameters including (1) common parameters taken from the literature such as the coefficient of risk aversion, productivity dispersion parameter, and elasticity of substitution between sectors, (2) sector-specific factors including capital intensity and consumption weights in the tradable bundle, (3) country-specific factors including aggregate labor and capital endowments, trade costs, expenditure shares on the nontradable sector, and (4) country-sector-specific productivity. Some of these parameters can be taken from data; others need to be estimated by imposing the model structure. I discuss them in turn.

Table A.3 lists the parameters whose values are obtained from previous literature. For instance, Eaton and Kortum (2002) estimate θ, which captures dispersion of productivity, to be 8.28. Levchenko and Zhang (2014) set the elasticity of substitution between tradable sectors equal to 2. Lastly, the coefficient of risk aversion is assumed to be 2 and the annual discount factor is 0.95, both of which are common values found in the literature.

Regarding sector-specific parameters, I follow Di Giovanni et al. (2014) in choosing the values for factor intensity and consumption weights. They use the U.S. Input-Output Matrix to obtain capital intensity α_s, and use the U.S. consumption data to compute taste parameters ψ_s in the consumption bundle. Table A.4 lists the sector-specific parameters for the 15 tradable sectors in the sample.

For country-level parameters, data on capital stock and labor force are taken directly from the Penn World Table. The shares of expenditure on traded goods (μ) are obtained from the STAN Database for OECD countries. For countries not covered by STAN, I calculate μ as the value predicted by a linear regression that captures the relationship between μ, consumption as shares of GDP, and GDP per capita. Table A.5 lists the shares of expenditure on tradable goods for the countries in the sample. Lastly, country-level trade costs are computed to fit a country's overall export-to-output ratio when sectoral productivity is estimated.[12]

The procedure I use to estimate sectoral productivity is modified from Shikher (2011) and Di Giovanni et al. (2014). I impose fewer constraints than those earlier studies in order to keep the estimation simple and the following portfolio choice problem tractable. Sectoral productivity and trade costs are estimated to match (1) country i's share of all the countries' exports in sector s (denoted as $\pi_{i,s}$), and (2) the country's overall export-to-output ratio (denoted as $x2y_i$). Data on sectoral trade are taken from the UN Comtrade Database, and export-to-output ratios are from the Penn World Table. I use the 2005 data for baseline estimation. The algorithm used to estimate model parameters and solve the model is outlined below.

Step 1. Guess factor prices under the Cobb-Douglas assumption using output and endowment data :

$$r_i = \alpha_i \frac{Y_i}{K_i}, \qquad w_i = (1-\alpha_i)\frac{Y_i}{L_i},$$

where α_i is country-specific capital share, which is also available in the Penn World Table.

Step 2. Estimate sectoral productivity $T_{i,k}$ and trade cost τ_i to fit a country's trade pattern. It involves the following steps:

[12] In the trade literature, iceberg trade costs are normally estimated in a gravity model with geographic distance, free-trade zone, and common borders, among other factors, as the determinants of bilateral trade flows. This approach is not applicable here since I focus on a country's overall trade ties with the rest of the world instead of with a single trade partner. Meanwhile, as is argued by Bernard et al. (2003) and many other papers, overall trade matrix is a sufficient statistic for trade costs in simulating a model. This is the rationale I use to estimate a country's trade costs from its exports-to-GDP ratio.

Step 2.1. Compute the cost and price of tradable sectors using the following equations:

$$c_{i,s} = r_i^{\alpha_s} w_i^{1-\alpha_s}$$

$$\Phi_s = \sum_i^I T_{i,s}(\tau_i c_{i,s})^{-\theta}$$

$$\Phi_{i,s} = \Phi_s - T_{i,s}(\tau_i^{-\theta} - 1)c_{i,s}^{-\theta}$$

$$P_{i,s} = [\Gamma(\frac{\theta + 1 - \epsilon}{\theta})]^{\frac{1}{1-\epsilon}} \Phi_{i,s}^{-\frac{1}{\theta}}$$

$$P_{i,T}^{1-\phi} = \sum_{s=1}^S \psi_s P_{i,s}^{1-\phi}$$

Step 2.2. Based on prices, calculate consumers' aggregate expenditures and their demand for specific goods.

$$P_i C_i = w_i L_i + r_i K_i$$

$$y_{i,s} = \mu_i P_i C_i \psi_s (\frac{P_{i,s}}{P_{i,T}})^{1-\phi}$$

Step 2.3. Calculate the cost, demand, productivity, and price of the nontradable sector.

$$c_{i,N} = r_i^{\alpha_N} w_i^{1-\alpha_N}$$

$$y_{i,N} = (1 - \mu_i) P_i C_i$$

$$T_{i,N} = \frac{y_{i,N}}{A K_{i,N}^{\alpha_N} L_{i,N}^{1-\alpha_N}} \qquad where \qquad A = \alpha_N^{-\alpha_N}(1-\alpha_N)^{\alpha_N - 1}$$

$$P_{i,N} = \Gamma(\frac{\theta + 1 - \epsilon}{\theta})]^{\frac{1}{1-\epsilon}} T_{i,N}^{-\frac{1}{\theta}} c_{i,N}$$

Step 2.4. Given demand, compute productivity and trade costs to match $\pi_{i,s}$ and $x2y_i$.

$$\pi_{i,s} = \frac{T_{i,s}(\tau_i c_{i,s})^{-\theta}}{\Phi_s}$$

$$x2y_i = \frac{\sum_{s=1}^{S} \pi_{i,s} \sum_{j \neq i}^{I} y_{j,s}}{y_{i,N} + \sum_{s=1}^{S} y_{i,s} T_{i,s} c_{i,s}^{-\theta} / \Phi_{i,s}}$$

After estimating trade cost and productivity, I numerically solve the equilibrium of the model by following the steps below.

Step 3. Plug the estimated $T_{i,s}$ and τ_i in the equations from Step 2.1 to Step 2.3. Determine factor allocations based on the Cobb-Douglas production.

$$L_{i,s} = (1 - \alpha_s) \frac{\sum_{s=1}^{S} \pi_{i,s} \sum_{j \neq i} y_{j,s} + T_{i,s} c_{i,s}^{-\theta} / \Phi_{i,s} y_{i,s}}{w_i}$$

$$K_{i,s} = \alpha_s \frac{\sum_{s=1}^{S} \pi_{i,s} \sum_{j \neq i} y_{j,s} + T_{i,s} c_{i,s}^{-\theta} / \Phi_{i,s} y_{i,s}}{r_i}$$

$$L_{i,N} = (1 - \alpha_N) \frac{y_{i,N}}{w_i}$$

$$K_{i,N} = \alpha_N \frac{y_{i,N}}{r_i}$$

Step 4. Update factor prices w_i, r_i, repeat Step 2 and 3, until the prices satisfy the market-clearing conditions:

$$\sum_{k \in \{1,2,\ldots,S,N\}} L_{i,k} = L_i, \qquad \sum_{k \in \{1,2,\ldots,S,N\}} K_{i,k} = K_i.$$

After deriving all the countries' domestic variables, I recover foreign variables relative to each country based on the goods market clearing conditions. At this point, all the variables on the real side of the economy have been determined. Before analyzing portfolio choices inferred by the model, I evaluate the model's fit by (1) comparing sectoral trade flows predicted by the model to trade data, and (2) comparing model-implied wage rate to the data in the Penn World Table. In Appendix C, I show that the model performs well in matching these two targets.

Step 5. Solve the portfolio choice problem using Devereux and Sutherland (2007)'s method.

This method combines a second-order approximation of the portfolio Euler equation with a first-order approximation of all the other equations in the model to calculate households' optimal portfolio. The solution captures the correlation between asset returns and macro fundamentals and hence reflects households' risk-hedging motives. In the two-country two-sector baseline model, this method yields the same result as the analytical solution in Section 2. Here, I apply the method to an extended case in which each household chooses among $(S + 1) \times 2$ assets, representing S tradable and 1 nontradable sectors at home and abroad.

4.3 Numerical Results

In this section, I first confront the numerical solution to the model with data to evaluate its performance. I find that (1) the model successfully predicts the negative correlation between home bias and industrial specialization, and (2) the model-implied financial friction matches well with the Chinn-Ito index.

Table 2 and Figure 1 establish the negative correlation between home bias and industrial specialization implied by the model. In column (1) of Table 2, the model indicates that, when HHI increases by 1, home bias decreases by 3.744. It is greater in magnitude than 0.947 in the data (column (2)). This can be attributed to the fact that, institutional and informational frictions in international financial markets also contribute to home bias in the real world, dwarfing the influence of industrial structure. This explains why the constant term's coefficient is significant in the data but insignificant in the model. Figure 1 illustrates that the model successfully predicts that highly specialized oil exporters, including Qatar and Norway, exhibit significantly lower home bias than more diversified economies such as the United States and Australia. Nevertheless, the especially low home bias of China, the Philippines, and Russia seems inconsistent with the data. For these countries, capital account restrictions prohibit investors from holding foreign assets, causing the divergence between the model and data.

Another angle from which to evaluate the model performance is to examine whether the model-implied financial friction lines up with other measures of capital restriction. As is shown in Figure 1, most countries exhibit negative home bias absent capital restriction, which indicates that investors rely heavily on international risk hedging given the world industrial structure. The difference between model-implied and actual holdings of domestic assets can be used as a proxy for financial friction. Therefore I compare this model-consistent financial friction with the Chinn-Ito index. As is mentioned earlier, the Chinn-Ito index is a de jure measure of capital account openness. Higher index values indicate greater financial openness. Column (3) of Table 2 shows that in a bivariate linear regression, the model-implied financial friction decreases in the Chinn-Ito index at the 5 percent significance level. Figure A.3 plots and confirms this correlation: almost all the OECD countries have high levels of financial liberalization, so their Chinn-Ito index values are high and model-implied financial frictions are low. In contrast, countries such as China, Russia, and the Philippines are subject to great capital account restrictions, consistent with the argument raised earlier.

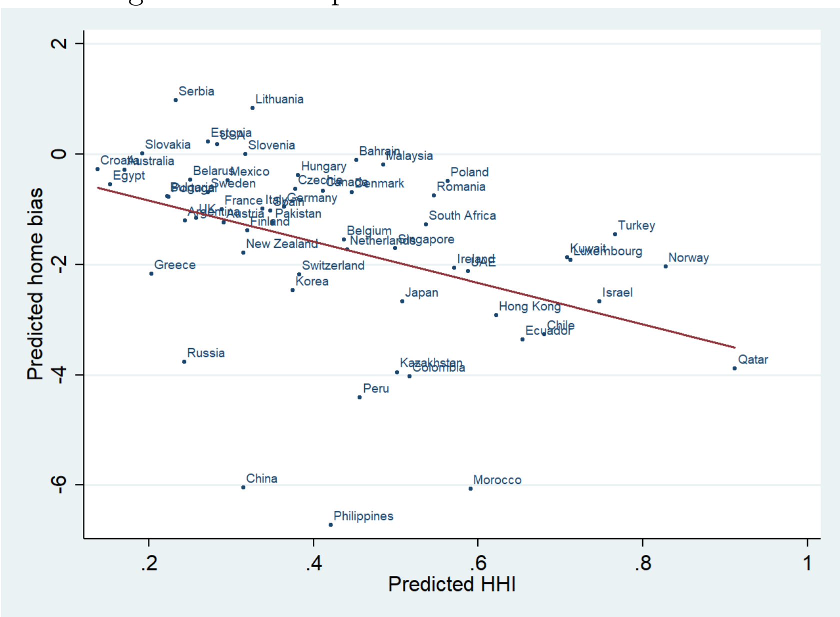
After discussing the numerical results and evaluating the model performance, I simulate the model in a counterfactual scenario with no specialization. In this counterfactual exercise, I assume that there is no productivity difference across sectors within a country

Table 2: Model vs Data

	Dep. Var: Home Bias		Dep. Var: Model-implied Financial Openness	
	Model	Data		
	(1)	(2)		(3)
HHI	-3.744 ***	-0.947 *	Chinn-Ito	-0.555 **
	(0.820)	(0.525)		(0.277)
Constant	-0.089	0.606 ***	Constant	4.031 ***
	(0.40)	(0.068)		(0.601)
Observations	58	37		36
R^2	0.171	0.026		0.193

Note: Robust standard errors. *significant at 10%, **significant at 5%, and *** significant at 1%. In columns (1) and (2), I compare the correlation between home bias and HHI in the model with that in the data. In column (3), I regress model-implied financial restrictions, measured as the difference between theoretical and actual domestic asset holdings, on the Chinn-Ito index as a way to test the model's performance.

Figure 1: Model-predicted Home Bias and HHI



Note: This figure plots the home bias and specialization indices (HHI) as predicted by the model.

— sectoral productivity is set to be the national average sectoral productivity. Table A.6 presents the model-implied home bias and industrial specialization in the original model and the counterfactual exercise. Given the homogeneous sectoral productivity, countries' industrial specialization proxied by HHI falls from 0.43 to 0.20 on average, a reduction of 53.5 percent. Meanwhile, home bias increases by 2.97 (178 percent) on average. When I regress the difference in home bias (ΔHB) on the difference in specialization (ΔHHI) between the two cases,

$$\Delta HB = \alpha + \beta \Delta HHI + \epsilon,$$

the estimated β is -6.27, and it is significantly negative at the 5 percent level.

This counterfactual analysis reiterates the influence of industrial specialization on home bias. When an economy becomes more industrially diversified, both the correlation among domestic industries and the influence of major industries on the overall economy fall significantly. Consequently, investors switch from international to intranational risk-hedging, thanks to the growing hedging benefits of holding domestic assets. As a result, home bias is tremendously higher than that in the original model.

An interesting implication of the numerical exercise is that, if countries become increasingly specialized because world goods markets grow more integrated, equity home bias will keep falling. This mechanism, together with reductions in transaction barriers in international financial markets, can lead to further decreases in home bias. Therefore, the home bias phenomenon will be even less puzzling in the future.

5 Conclusion

This paper examines the well-known home bias puzzle from a new perspective by linking portfolio diversification and industrial structure. I embed portfolio choice in a multi-country, multi-sector Eaton-Kortum trade framework to study how differences in sectoral productivity drive the variation in home bias across countries.

First I build a two-country, two-sector symmetric model to illustrate the interesting interaction between intranational risk hedging across sectors and international risk hedging across countries. Second, to empirically test the model's prediction that home bias decreases as industrial specialization rises, I use unique datasets to construct the home bias (HB) and Herfindahl-Hirschman indices (HHI). After confirming the hypothesis, I conduct a numerical assessment of an extended model. The quantitative framework successfully replicates the negative correlation between HB and HHI. Last but not least, a counterfactual exercise based on the model shows that home bias will be significantly higher in a case without sectoral productivity differences within countries.

This paper, together with Hu (2017), contributes to the literature on home bias by adding the sectoral dimension. In these two papers, I do not distinguish between specific destinations but group the rest of the world as a whole. Future research can employ a similar framework to study the influence of bilateral trade ties on bilateral financial flows. Past literature that focuses on the geography of international capital flows include Aviat and Coeurdacier (2007) and Martin and Rey (2006). Another topic to explore is the impact of financial allocations on production and trade patterns, given that firms are subject to credit constraints (see Manova (2012)). By including these extensions, future research will deepen our understanding of the interplay between trade and financial globalization.

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Appendices

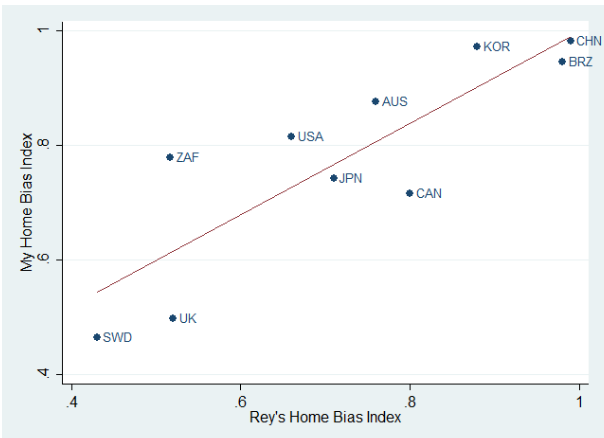
A Tables and Figures

Table A.1: Home Bias

Australia	0.797	France	0.424	Kuwait	0.376	Russia	0.955
Austria	0.099	Germany	0.210	Malaysia	0.983	Singapore	0.123
Bahrain	0.889	Greece	0.354	Mexico	0.939	Slovenia	0.809
Belgium	0.138	Hong Kong	0.184	Netherlands	0.097	South Africa	0.761
Brazil	0.836	Hungary	0.418	Norway	0.087	Spain	0.410
Canada	0.539	Ireland	0.238	Philippines	0.571	Sweden	0.463
China	0.953	Israel	0.891	Poland	0.939	Taiwan	0.773
Denmark	0.144	Italy	0.273	Portugal	0.747	UAE	0.836
Finland	0.599	Japan	0.488	Qatar	0.458	United Kingdom	0.393
		Korea	0.939	Romania	0.998	United States	0.666

Note: This table lists the home bias index. The formula for constructing the index is HB_i=1-Share of Foreign Equities in Country i Equity Holdings/Share of Foreign Equities the World Market Portfolio. The data are from Factset/Lionshare and Datastream.

Figure A.1: Comparison of Home Bias Constructed with Factset/Lionshare Data and IFS Data



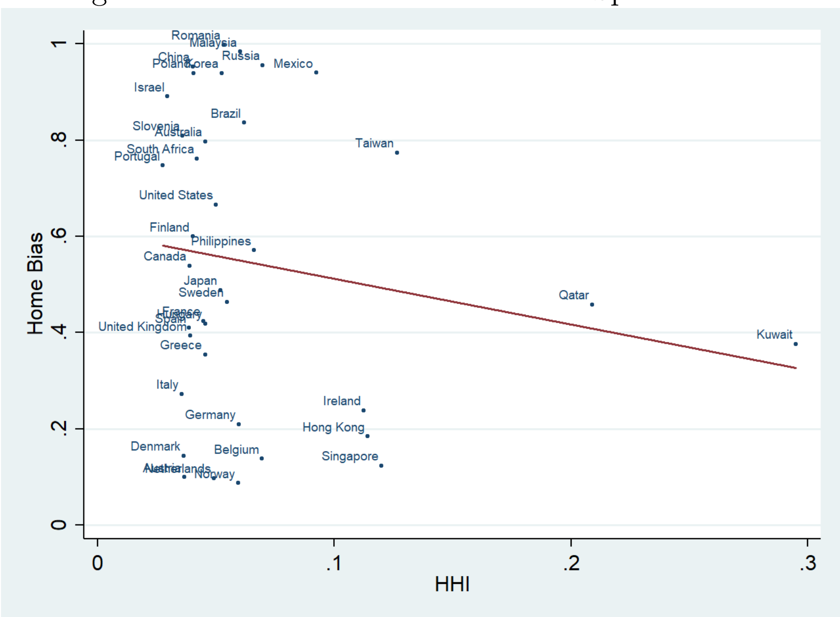
Note: This figure plots my home bias index against Coeurdacier and Rey (2013)'s (both as of 2008). I use the Factset/Lionshare data to construct the index, while they use the IFS data. The two indices are consistent since most of the points lie on or close to the 45 degree line.

Table A.2: Robustness Checks

Dep. Var: Home Bias	(1)	(2) Excluding oil exporters
HHI	-1.010 **	-2.788 **
	(0.495)	(1.385)
Chinn-Ito	-0.185 ***	-0.182 ***
	0.030	(0.031)
Constant	0.889 ***	0.984 ***
	(0.069)	(0.091)
Observations	36	33
R^2	0.525	0.552

Note: Robust standard errors in parentheses and standardized coefficients in brackets. **significant at 5%,***significant at 1%. The dependent variable is home bias. The independent variables include the Herfindahl-Hirschman Index (HHI) and the Chinn-Ito index.

Figure A.2: Home Bias and Industrial Specialization



Note: Figure A.2 plots the relationship between home bias and countries' specialization. The Herfindahl-Hirschman Index (HHI) is on the horizontal axis and home bias is on the vertical axis.

Table A.3: Parameterization in the Extended Model

Parameter	Description	Value
β	Discount factor	0.95
σ	Coefficient of relative risk aversion	2
ϕ	Elasticity of substitution between sectors	2
θ	Dispersion of productivity draws	8.28

Table A.4: Sector-specific Parameters

Sector Name	Expenditure Shares within Tradables (ψ_s)	Capital Intensity (α_s)
Food	0.165	0.329
Beverages	0.054	0.272
Tobacco	0.010	0.264
Clothing & Accessories, Footwear	0.134	0.491
Forestry	0.009	0.452
Paper	0.013	0.366
Oil & Gas Producers,Coal	0.096	0.244
Chemicals	0.008	0.308
Pharmeceutical	0.036	0.319
Iron & Steel	0.015	0.381
Nonferrous Metals	0.074	0.407
Electronics & Electric Equipement	0.060	0.405
Machinery	0.073	0.473
Automobiles & Parts	0.183	0.464
Furnishings	0.068	0.460

Note: ψ_s and α_s are estimated and compiled by Di Giovanni et al. (2014). Most of their sectors line up with mine, and I make modifications for the sectors that do not. For instance, I disaggregate their SIC 15 industry into "food" and "beverage" based on consumption shares using the data from BEA Table 2.3.5.U. I also normalize all the weights so that they add up to 1.

Table A.5: Expenditure Shares on Tradable Sectors

Argentina	0.507	Ecuador	0.543	Luxembourg	0.521	Russian Federation	0.578
Australia	0.615	Egypt	0.458	Malaysia	0.568	Serbia	0.488
Austria	0.413	Estonia	0.602	Mexico	0.55	Singapore	0.526
Bahrain	0.587	Finland	0.474	Morocco	0.567	Slovakia	0.594
Belarus	0.573	France	0.468	Netherlands	0.475	Slovenia	0.579
Belgium	0.497	Germany	0.484	New Zealand	0.472	South Africa	0.552
Bulgaria	0.537	Greece	0.444	Norway	0.526	Spain	0.507
Canada	0.461	Hungary	0.563	Pakistan	0.475	Sweden	0.484
Chile	0.503	Ireland	0.492	Peru	0.528	Switzerland	0.375
China	0.648	Israel	0.436	Philippines	0.498	Turkey	0.536
Hong Kong	0.424	Italy	0.496	Poland	0.608	United States	0.379
Colombia	0.472	Japan	0.404	Portugal	0.501	U.A.E.	0.475
Croatia	0.542	Kazakhstan	0.555	Qatar	0.558	United Kingdom	0.437
Czech	0.541	Kuwait	0.572	Rep. of Korea	0.425		
Denmark	0.466	Lithuania	0.722	Romania	0.535		

Note: This table lists countries' expenditure shares of tradables (ν_i). ν_i is mainly taken from the OECD data on household consumption expenditures. For some countries that are missing in the dataset, I compute μ as the value predicted by a linear regression that captures the relationship between μ, consumption as shares of GDP, and GDP per capita.

Figure A.3: Model-implied Financial Friction and Chinn-Ito Index

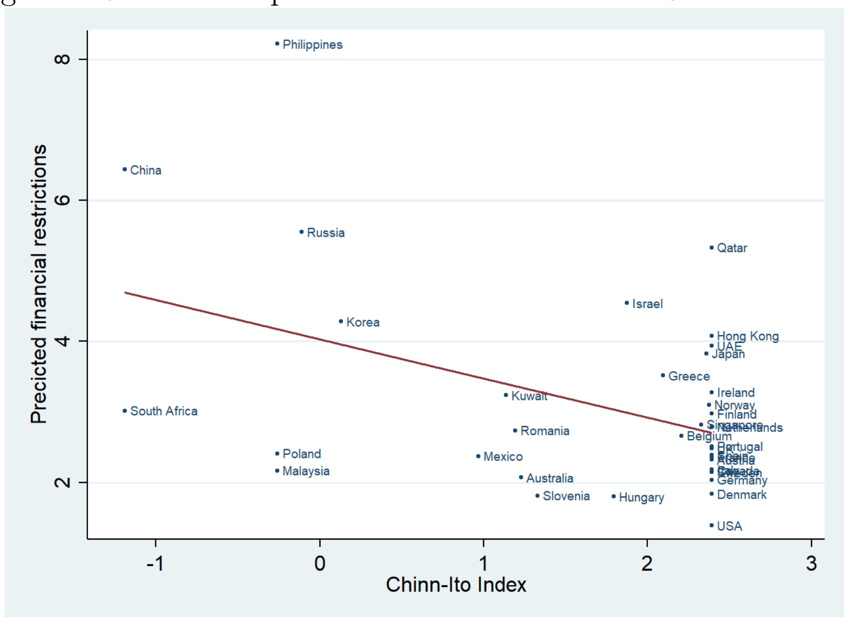


Table A.6: Model Results

	Original Model (1)		Counterfactual Exercise (2)		Difference (3)	
Country	Home Bias	HHI	Home Bias	HHI	Δ Home Bias	Δ HHI
Australia	-0.29	0.17	1.01	0.22	1.30	0.05
Austria	-1.24	0.29	0.83	0.21	2.07	-0.08
Belgium	-1.55	0.44	0.46	0.22	2.01	-0.22
Canada	-0.67	0.41	0.92	0.21	1.59	-0.20
China	-6.04	0.32	1.72	0.18	7.76	-0.14
Hong Kong	-2.92	0.62	0.83	0.22	3.75	-0.40
Denmark	-0.70	0.45	0.92	0.21	1.62	-0.24
Finland	-1.38	0.32	0.53	0.22	1.91	-0.10
France	-1.00	0.29	0.94	0.21	1.94	-0.08
Germany	-0.96	0.36	0.94	0.21	1.90	-0.15
Greece	-2.17	0.20	0.69	0.21	2.86	0.01
Hungary	-0.39	0.38	1.42	0.17	1.81	-0.21
Ireland	-2.06	0.57	0.34	0.21	2.40	-0.36
Israel	-2.67	0.75	0.65	0.20	3.32	-0.55
Italy	-0.99	0.34	0.91	0.22	1.90	-0.12
Japan	-2.67	0.51	0.99	0.21	3.66	-0.30
Kuwait	-1.87	0.71	1.53	0.22	3.40	-0.49
Malaysia	-0.20	0.48	1.16	0.16	1.36	-0.32
Mexico	-0.48	0.30	0.66	0.15	1.14	-0.15
Netherlands	-1.73	0.44	0.84	0.21	2.57	-0.23
Norway	-2.04	0.83	2.19	0.22	4.23	-0.61
Philippines	-6.72	0.42	-0.38	0.17	6.34	-0.25
Poland	-0.49	0.56	1.15	0.16	1.64	-0.40
Portugal	-0.77	0.22	-0.36	0.20	0.41	-0.02
Qatar	-3.88	0.91	6.97	0.22	10.85	-0.69
Rep. of Korea	-2.46	0.37	0.95	0.20	3.41	-0.17
Romania	-0.75	0.55	5.69	0.15	6.44	-0.40
Russia	-3.77	0.24	1.14	0.16	4.91	-0.08
Singapore	-1.71	0.50	2.41	0.23	4.12	-0.27
Slovenia	0.00	0.32	3.43	0.21	3.43	-0.11
South Africa	-1.28	0.54	1.56	0.14	2.84	-0.40
Spain	-1.02	0.35	-0.16	0.20	0.86	-0.15
Sweden	-0.69	0.27	0.62	0.21	1.31	-0.06
USA	0.18	0.28	0.98	0.22	0.80	-0.06
UK	-1.15	0.26	0.96	0.21	2.11	-0.05
Min	-6.72	0.17	-0.38	0.14	0.41	-0.69
Max	0.18	0.91	6.97	0.23	10.85	0.05
Mean	-1.67	0.43	1.30	0.20	2.97	-0.23

Note: This table presents the home bias and the industrial specialization indices (HHI) as predicted by the model. Column (1) lists the results from the original model, while column (2) lists those from the counterfactual exercise absent sectoral productivity differences. Column (3) shows the difference between the two.

B Proofs

B.1 Model Log-linearization

In this section I log-linearize the model around its steady state and evaluate the effect of sectoral productivity shocks on the relative wage and exchange rate. The answer helps us understand the roles that different assets play in risk hedging and how investors choose their optimal equity portfolio.

In the baseline case, I assume the two countries are symmetric for simplification purposes. They have the same amount of labor, and their within-country relative productivity and preference of goods are also symmetric. These assumptions make it easier to derive analytical solutions and allow us to concentrate on the main mechanism of the model. Many of the assumptions can be relaxed in extended models.

I assume the productivity levels in the steady state are

$$\bar{T}_{H,b} = \bar{T}_{F,a} = 1, \qquad \bar{T}_{H,a} = \bar{T}_{F,b} = T > 1$$

Since there is no trade cost, goods prices are the same across countries with the law of one price (LOOP). The price of sector a goods relative to sector b goods follows

$$s \equiv \frac{P_a}{P_b} = [\frac{T_{H,a}w_H^{-\theta} + T_{F,a}w_F^{-\theta}}{T_{H,b}w_H^{-\theta} + T_{F,b}w_F^{-\theta}}]^{-\frac{1}{\theta}} = [\frac{T_{H,a}w^{-\theta} + T_{F,a}}{T_{H,b}w^{-\theta} + T_{F,b}}]^{-\frac{1}{\theta}}$$

Given the CPI-based real exchange rate $e = \frac{P_H}{P_F}$, we can find the link between the changes in the relative sectoral price s and those in the exchange rate e under the CES utility:

$$\hat{e} = (2\psi - 1)\hat{s}.$$

where $\hat{x} = log\frac{x_t - \bar{x}}{x}$ is the log-deviation of a variable from its steady state.

Based on Backus and Smith (1993), the changes in the relative marginal utility across countries are proportional to the changes in the consumption-based real exchange rate as

$$-\sigma(\hat{C}_H - \hat{C}_F) = \hat{e}$$

Hence, the relative price-adjusted aggregate consumption $\frac{P_H C_H}{P_F C_F}$ follows

$$\hat{PC} = \hat{P} + \hat{C} = (1 - \frac{1}{\sigma})\hat{e} = (2\psi - 1)(1 - \frac{1}{\sigma})\hat{s}.$$

Now let us focus on the covariance between financial returns. In our model, asset returns of country i sector s at time t are equal to the sum of dividends and changes in the price of equities

$$r_{i,s,t} = \frac{q_{i,s,t} + d_{i,s,t}}{q_{i,s,t-1}}.$$

Coeurdacier et al. (2010) and Coeurdacier (2009) show that a "static" budget constraint condition is equivalent to a dynamic budget constraint condition (equations 1,2) up to a first order approximation. In the static budget constraint with no future variables, the prices of equities q disappear and the covariance between financial returns is solely dependent on the covariance between dividends.

Within a sector, the relative dividend at home versus abroad ($d_s = \frac{d_{H,s}}{d_{F,s}}, s \in \{a, b\}$) is equal to the relative market shares of the two countries in sector s:

$$\hat{d}_s = \hat{T}_s - \theta\hat{w}.$$

Within a country, the relative dividend in sector a versus sector b ($d_i = \frac{d_{i,a}}{d_{i,b}}, i \in \{H, F\}$) becomes

$$\hat{d}_i = \hat{T}_i + [\theta - \phi + 1 + (2\psi - 1)^2(\phi - \frac{1}{\sigma})]\hat{s}$$

From the expressions, we find that the covariances between dividends depend not only on productivity shocks themselves, but also on their impact on the relative wage and exchange rate.

Denote the difference between the productivity shocks of the two countries' productive sectors as $\hat{T}_1 \equiv \hat{T}_{H,a} - \hat{T}_{F,b}$ and that of the unproductive sectors as $\hat{T}_2 \equiv \hat{T}_{H,b} - \hat{T}_{F,a}$. With the Eaton-Kortum framework which links goods supply to labor cost, a pair of productivity shocks $(\hat{T}_1, \hat{T}_2)$ is uniquely mapped to a pair of wages and prices changes $(\hat{w}, \hat{s})$. The relative wage at home is equal to the relative price-adjusted aggregate production, thus

$$\hat{w} = \frac{1}{1+\theta}\{\frac{T-1}{T+1}[1+\theta-\phi+(2\psi-1)^2(\phi-\frac{1}{\sigma})]\hat{s} + \frac{T}{T+1}\hat{T}_1 + \frac{1}{T+1}\hat{T}_2$$

Moreover, the log-linearization of the relative price yields

$$\hat{s} = \frac{T-1}{T+1}\hat{w} + \frac{1}{\theta}\frac{1}{T+1}[-T\hat{T}_1 + \hat{T}_2]$$

Hence, sectoral productivity shocks affect relative labor income and real exchange rate given

$$\hat{s} = \{(T+1)^2(1+\theta)-(T-1)^2\lambda\}^{-1}\{[(T-1)T-\frac{\theta+1}{\theta}(T+1)T]\hat{T}_{H,a}+[T-1+\frac{\theta+1}{\theta}(T+1)]\hat{T}_{H,b}$$

$$+[(T-1)(-1)-\frac{\theta+1}{\theta}(T+1)]\hat{T}_{F,a} + [-(T-1)T+\frac{\theta+1}{\theta}(T+1)T]\hat{T}_{F,b}\}$$

$$\hat{w} = \{(T+1)^2(1+\theta)-(T-1)^2\lambda\}^{-1}\{[(T+1)T-\frac{\lambda}{\theta}(T-1)T]\hat{T}_{H,a}+[(T+1)-\frac{\lambda}{\theta}(T-1)(-1)]\hat{T}_{H,b}$$

$$+[(T+1)(-1)-\frac{\lambda}{\theta}(T-1)]\hat{T}_{F,a} + [(T+1)(-T)-\frac{\lambda}{\theta}(T-1)(-T)]\hat{T}_{F,b}\}$$

where $\lambda \equiv 1+\theta-\phi+(2\psi-1)^2(\phi-\frac{1}{\sigma})$.[13]

There are two parts in each of the coefficients. The first one denotes the direct effect of sectoral productivity shocks on s or w, and the second denotes the indirect effect induced by demand changes. For instance, the coefficient of $\hat{T}_{H,a}$ in $\hat{w}$ consists of $T(T+1)$ (direct effect) and $-\lambda\frac{T(T-1)}{\theta}$ (indirect effect). With the direct effect, the productivity boost raises the domestic income. With the indirect effect, domestic labor income decreases due to the lower price of exports. The overall influence of the shock depends on which effect dominates.

B.2 Proof of Proposition 1

The difference between the two countries' budget constraints follows

$$\frac{1}{\alpha}\hat{PC}-\frac{1-\alpha}{\alpha}\hat{wL}=[\mu S_a-(1-\mu)(1-S_b)]\hat{d}_a+[(1-\mu)S_b-\mu(1-S_a)]\hat{d}_b+(2\mu-1)\hat{d}_F$$

$\chi(x_1,x_2)$ is the covariance between x_1 and x_2. $\chi^2(x)$ is the variance of variable x. I also denote the sum of the covariances of variable $\hat{x}$ with $\hat{d}_a,\hat{d}_a$ as $\sum\chi(\hat{x})$. When we take the covariance between $\hat{d}_s$ and all the other variables, we find

$$\begin{aligned}\frac{1}{\alpha}(1-\frac{1}{\sigma})\chi(\hat{e},\hat{d}_a)-\frac{1-\alpha}{\alpha}\chi(\hat{wL},\hat{d}_a)&=[\mu S_a-(1-\mu)(1-S_b)]\chi^2(\hat{d}_a)\\&+[(1-\mu)S_b-\mu(1-S_a)]\chi(\hat{d}_b,\hat{d}_a)+(2\mu-1)\chi(\hat{d}_F,\hat{d}_a)\\\frac{1}{\alpha}(1-\frac{1}{\sigma})\chi(\hat{e},\hat{d}_b)-\frac{1-\alpha}{\alpha}\chi(\hat{wL},\hat{d}_b)&=[\mu S_a-(1-\mu)(1-S_b)]\chi(\hat{d}_a,\hat{d}_b)\\&+[(1-\mu)S_b-\mu(1-S_a)]\chi^2(\hat{d}_b)+(2\mu-1)\chi(\hat{d}_F,\hat{d}_b)\end{aligned}$$

[13] Since the elasticity of substitution between tradable goods is above unity (the literature, including Levchenko and Zhang (2014), sets it equal to 2), $\lambda<\theta$ always holds.

$$\Rightarrow \frac{1}{\alpha}(1-\frac{1}{\sigma})\Sigma\chi(\hat{e}) - \frac{1-\alpha}{\alpha}\Sigma\chi(\hat{wL}) = (2\mu-1)\Sigma\chi(\hat{d}_F)$$
$$+ [\mu S_a - (1-\mu)(1-S_b) + (1-\mu)S_b - \mu(1-S_a)]$$
$$\times (\chi^2 + \chi(\hat{d}_a, \hat{d}_b))$$

Sectoral technological shocks are i.i.d. and countries are symmetric, so the following equations hold

$$\chi^2(\hat{d}_a) = \chi^2(\hat{d}_b) = \chi^2, \qquad \Sigma\chi(\hat{d}_F) = \Sigma\chi(\hat{d}_H)$$

When I plug them back in and rearrange the equation, I obtain the aggregate domestic share as

$$\mu S_a + (1-\mu)S_b = \frac{1}{2} + [\frac{\sigma-1}{2\sigma\alpha}\sum\chi(\hat{e}) - \frac{1-\alpha}{2\alpha}\sum\chi(\hat{wL}) - \frac{2\mu-1}{2}\sum\chi(\hat{d}_H)][\chi^2 + \chi(\hat{d}_a, \hat{d}_b)]^{-1}$$

Next, I determine the sign of $\chi^2 + \chi(\hat{d}_a, \hat{d}_b)$:

$$\chi^2 + \chi(\hat{d}_a, \hat{d}_b) = [(2\theta T(1 - \frac{\lambda\frac{T-1}{T+1}}{\theta}) - 1]^2 + [2\theta(1 + \frac{\lambda\frac{T-1}{T+1}}{\theta}) - 1]^2 > 0$$

Since it has a positive sign, the coefficient of labor income in equation 5 is negative and the coefficient of the real exchange rate is positive when $\sigma > 1$.

B.3 Proof of Proposition 3

The difference between domestic and foreign budget constraints can be written as

$$\frac{1}{\alpha}\hat{PC} - \frac{1-\alpha}{\alpha}\hat{wL} = [\mu S_a - (1-\mu)(1-S_b)]\hat{d}_1 + [(1-\mu)S_b - \mu(1-S_a)]\hat{d}_2$$

where $\hat{d}_1$ and $\hat{d}_2$ can represent $\hat{d}_1 = \hat{d}_{H,a} - \hat{d}_{F,b} = \lambda s + \hat{T}_1 - \theta\hat{w}$, $\quad \hat{d}_2 = \hat{d}_{H,b} - \hat{d}_{F,a} = -\lambda\hat{s} + \hat{T}_2 - \theta\hat{w}$. Moreover, a pair of $(\hat{T}_1, \hat{T}_2)$ is uniquely mapped to a pair of $(\hat{s}, \hat{w})$ via

$$\hat{T}_1 = \frac{1}{2T}[(1-T)\lambda - (T+1)\theta]\hat{s} + \frac{1}{2T}[(1+\theta)(T+1) + \theta(T-1)]\hat{w}$$

$$\hat{T}_2 = \frac{1}{2}[(T+1)\theta - \lambda(T-1)]\hat{s} + \frac{1}{2}[(1+\theta)(T+1) - \theta(T-1)]\hat{w}$$

Let $\Omega_1 = \mu S_a - (1-\mu)(1-S_b)$ and $\Omega_2 = (1-\mu)S_b - \mu(1-S_a)$. Plug this into the original budget constraint, and we will get an equation with $(\hat{s}, \hat{w})$ only:

$$(1-\frac{1}{\sigma})(2\psi - 1))\hat{s} = (1-\alpha)\hat{w} + \alpha\Omega_1(\lambda\hat{s} + \hat{T}_1 - \theta\hat{w}) + \alpha\Omega_2(-\lambda\hat{s} + \hat{T}_2 - \theta\hat{w})$$

$$\begin{aligned}
\Rightarrow (1-\frac{1}{\sigma})(2\psi - 1))\hat{s} = \{&1 - \alpha - \theta\alpha\Omega_1 - \theta\alpha\Omega_2 + \frac{\alpha\Omega_1}{2T}[(\theta+1)(T+1) + \theta(T-1)] \\
&+ \frac{\alpha\Omega_2}{2}[(\theta+1)(T+1) - \theta(T-1)]\}\hat{w} \\
&+ \{\alpha\lambda\Omega_1 - \alpha\lambda\Omega_2 + \frac{\alpha\Omega_1}{2T}[(1-T)\lambda - (T+1)\theta] \\
&+ \frac{\alpha\Omega_2}{2T}[(1-T)\lambda + (T+1)\theta]\}\hat{s}
\end{aligned}$$

The optimal portfolio ensues regardless of the w and s shocks in the economy. By matching the coefficients of $\hat{s}$ and $\hat{w}$, we get the expressions Ω_1 and Ω_2.

$$\Omega_1 \equiv \mu S_a - (1-\mu)(1-S_b) = \frac{T}{T+1}\frac{\alpha-1}{\alpha} + \frac{T}{T+1}\frac{1}{\alpha}\frac{(1-\frac{1}{\sigma})}{\lambda-\theta}$$

$$\Omega_2 \equiv (1-\mu)S_b - \mu(1-S_a) = \frac{1}{T+1}\frac{\alpha-1}{\alpha} - \frac{1}{T+1}\frac{1}{\alpha}\frac{(1-\frac{1}{\sigma})}{\lambda-\theta}$$

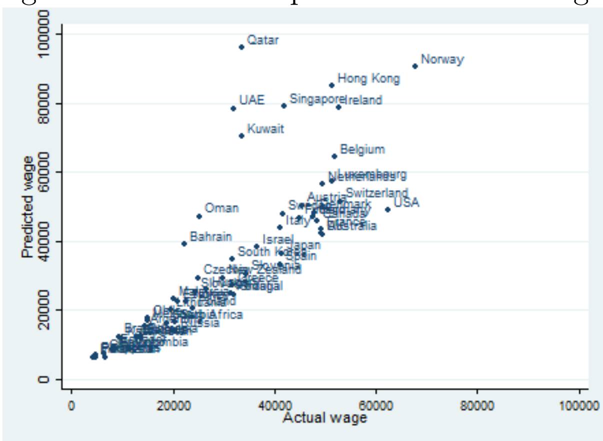
C Model Fit

In this section I evaluate the performance of the model in predicting wages and sectoral trade flows.

Figure C.1 plots the relationship between the wages predicted by the model and those calculated with the data in the Penn World Table.[14] As can be seen in the figure, the model does a good job of matching real-world observations since most of the countries lie on the 45-degree line. However, the model over predicts the wages in some countries, particularly oil exporters such as Norway, Qatar, and Kuwait. This happens because the gravity model over-estimates the labor hired by the lucrative oil industry. Therefore, the predicted national wage is higher than that in data averaged across industries. Apart from this, the model performs well, as the correlation between the actual and predicted wages exceeds 0.8.

Figure C.2 plots the predicted and actual sectoral exports of a country to the rest of

Figure C.1: Model-implied and Actual Wages

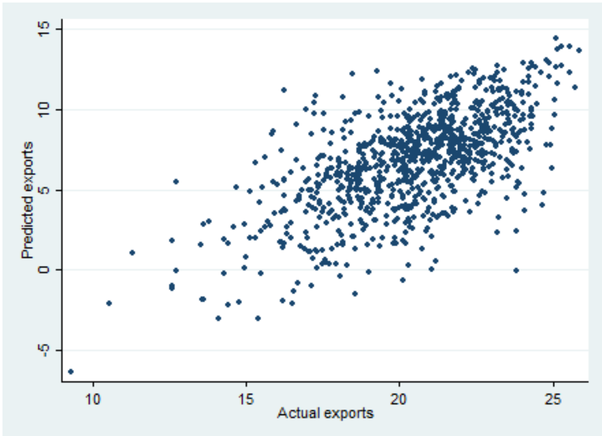


Note: This figure plots the relationship between model-implied and actual wages. Predicted wages are on the horizontal axis, and actual wages are on the vertical axis.

[14]The wage is calculated as Rgdpe(Expenditure-side real GDP at chained PPPs) × labsh(Share of labour compensation in GDP)/emp(Number of persons engaged)

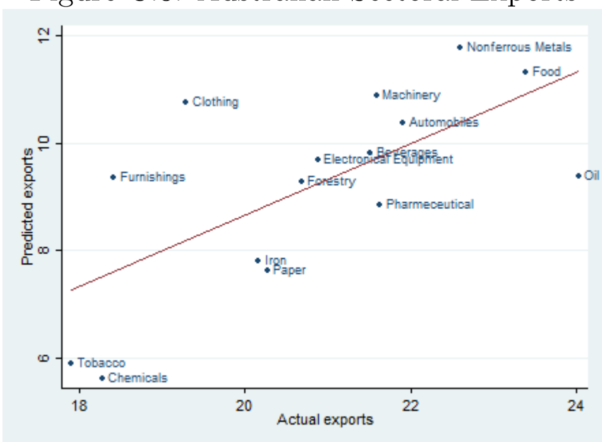
the world as another way to examine model fit. The model under-estimates the magnitude of trade volumes, which can be attributed to unbalanced trade and other factors that the model abstracts from. Nevertheless, the model does modestly well in predicting the relative pattern: the correlation between the predicted and actual trade flows is 0.63. Figure C.3 shows Australia as an example. The relative ranking of sectoral exports is mostly predicted by the model. Australia exports the least tobacco and chemicals and exports the most metals and food.

Figure C.2: Model-implied and Actual Sectoral Exports



Note: This figure plots the relationship between model-implied and actual sectoral exports in logs. Actual exports are on the horizontal axis, and predicted exports are on the vertical axis.

Figure C.3: Australian Sectoral Exports



Note: This figure plots the relationship between model-implied and actual sectoral exports (in logs) in Australia. Actual exports are on the horizontal axis, and predicted exports are on the vertical axis.