International Transmission through Product Quality and Variety: Missing Risk Sharing?

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Motivation

- We are happy consuming higher quality of goods.
- We are happy consuming higher number of product varieties.
- The above is of course true in open economy as well as in closed economy.
- In this paper, we explore international transmission mechanism and resulting international risk sharing taking into account fluctuations in product quality and the number of varieties.
- Changes in product quality and variety are not easy to capture by statistical agency. They only partially observe these changes. We investigate the extent of "missing risk sharing" with world trade data.

Theoretical framework

- We provide a simple two-country DSGE model that incorporates both endogenously determined product quality and the number of product varieties.
- Firms, each of which representing one product variety, are monopolistically competitive and heterogenous in terms of firm specific productivity.
- Assuming that higher quality of goods requires higher marginal cost in production, firms choose endogenously firm specific product quality.
- Through entry and exit of firms in exporting markets as well as domestic markets, the number of product varieties is endogenously determined.
- As the benchmark case, we consider the balanced trade. Our results are robust with another type of financial market (incomplete financial markets with state non-contigent bonds).

Literature

- Ghiorni and Melitz (2005): endogenous firm entry in a DSGE model.
- Verhoogen (2008), Verhoogen and Kugler (2012), Picard (2012) and Antoniades (2015):Endogenous choice of quality.
- Corsetti et al. (2008), Benigno and Thoenissen (2008) ,Hamano (2013) and Kucuk and Sutherland (2015): International risk sharing and the Backus-Smith puzzle (Kollmann 1995, Backus and Smith 1993).
- Broda and Weinstein (2004, 2010), Hummels and Klenow (2005), Baldwin and Harrigan (2011) and Feenstra and Romalis (2014): Empirical papers about product varieties and quality.
- Aghion et al. (2017): "Missing Growth" due to unobservable quality and variety changes in growth accounting in Shumpeterian growth model.

Results

- The theoretical model replicates the observed trade pattern. Following a rise in trade cost, with possibility of quality upgrading, firms charge higher prices. The Higher the distance is, the higher the price of exports is.
- International transmission arising from changes in product quality and the number of varieties is non negligible. Following a positive productivity shock in one country, other countries benefit from these margins. (ex. updated version of i-phone or more available varieties of french wine)

Results (Con't)

- (Lack) of international risk sharing (namely, the Backus-Smith puzzle) can be explained by taking into account changes in product quality under incomplete assets markets. Intuition: higher product quality works as a positive demand shock. As a result, the observable real exchange rate appreciates reflecting higher income due to the production of higher quality of goods. The BS correlation is thus *conditional* on the imperfectly observable changes in quality and varieties.
- With data, the conditional BS correlation tends to become more positive (closer to planner's allocation) with full sample while heterogeneity arises among different income groups of countries.
- Higher risk sharing among rich countries, but almost no risk sharing among poor through product quality and variety. Lesser extent of risk sharing through product quality and variety across rich and poor.

Structure of the presentation

- The model
- Calibration
- International Transmission in the theoretical model
- The Backus-Smith puzzle revisited
- The BS correlation with data
- Conclusion

Households

The representative household maximizes $E_t \sum_{i=t}^{\infty} \beta^{i-t} U_t$,

$$U_t = \frac{C_t^{1-\gamma}}{1-\gamma} - \chi \frac{L_t^{1+\frac{1}{\varphi}}}{1+\frac{1}{\varphi}},$$

$$\begin{aligned} C_t &= \left[C_{H,t}^{1-\frac{1}{\omega}} + C_{F,t}^{1-\frac{1}{\omega}} \right]^{\frac{1}{1-\frac{1}{\omega}}}, \\ C_{H,t} &= V_{H,t} \left(\int_{\zeta \in \Omega} q_D(\zeta)\, c_{D,t}(\zeta)^{1-\frac{1}{\sigma}} d\zeta \right)^{\frac{1}{1-\frac{1}{\sigma}}}, \\ C_{F,t} &= V_{F,t}^{*} \left(\int_{\vartheta \in \Omega} q_X^{*}(\vartheta)\, c_{X,t}(\vartheta)^{1-\frac{1}{\sigma}} d\vartheta \right)^{\frac{1}{1-\frac{1}{\sigma}}}, \end{aligned}$$

where $V_{H,t} \equiv N_{D,t}^{\psi-\frac{1}{\sigma-1}}$ and $V_{F,t}^{*} \equiv N_{X,t}^{*\psi-\frac{1}{\sigma-1}}$. At any given time t, only a subset of goods $\Omega_t \in \Omega$ is available.

Optimal demands

The optimal consumption for each domestic, imported basket and individual product variety is found to be

$$C_{H,t} = \left(\frac{P_{H,t}}{P_t}\right)^{-\omega} C_t, \qquad C_{F,t} = \left(\frac{P_{F,t}}{P_t}\right)^{-\omega} C_t.$$

$$c_{D,t}(\zeta) = (V_{H,t} q_D(\zeta))^{\sigma-1} \left(\frac{p_{D,t}(\zeta)}{P_{H,t}}\right)^{-\sigma} C_{H,t}, \tag{1}$$

$$c_{X,t}(\vartheta) = \left(V^*_{F,t} q^*_X(\vartheta)\right)^{\sigma-1} \left(\frac{p^*_{X,t}(\vartheta)}{P_{F,t}}\right)^{-\sigma} C_{F,t}. \tag{2}$$

Price indices

$$P_t = \left[P_{H,t}^{1-\omega} + P_{F,t}^{1-\omega}\right]^{\frac{1}{1-\omega}},$$

$$P_{H,t} = \frac{1}{V_{H,t}} \left(\int_{\zeta \in \Omega_t} \left(\frac{p_{D,t}(\zeta)}{q_D(\zeta)} \right)^{1-\sigma} d\zeta \right)^{\frac{1}{1-\sigma}},$$

$$P_{F.t} = \frac{1}{V_{F.t}^*} \left(\int_{\vartheta \in \Omega_t} \left(\frac{p_{X,t}^*(\vartheta)}{q_X^*(\vartheta)} \right)^{1-\sigma} d\vartheta \right)^{\frac{1}{1-\sigma}}.$$

Finally, we choose the welfare-based consumer price index, P_t, as numéraire in Home and define real prices as $\rho_{H,t} \equiv \frac{P_{H,t}}{P_t}$, $\rho_{F,t} \equiv \frac{P_{F,t}}{P_t}$, $\rho_{D,t}(\zeta) \equiv \frac{p_{D,t}(\zeta)}{P_t}$ and $\rho_{X,t}^*(\vartheta) \equiv \frac{p_{X,t}^*(\vartheta)}{P_t}$. And the real exchange rate: $Q_t \equiv P_t^* / P_t$.

Entry and Export

In every period, there is a mass of $N_{E,t}$ entrants. Prior to entry, these new entrants are identical and face a *sunk* entry cost of f_E which is defined as follows

$$f_E = Z_{E,t} l_{E,t}, \tag{3}$$

where $Z_{E,t}$ denotes labor productivity level which is specific for firm setup. $l_{E,t}$ is the demand for labor in firm setup. Upon entry, firms draw their productivity level z from a distribution $G(z)$ with support on $[z_{\min}, \infty)$. Exporting requires an *operational* fixed cost f_X in every period:

$$f_X = Z_t l_{f_X,t}, \tag{4}$$

where $l_{f_X,t}$ is demand for labor required in producing f_X amount of fixed costs.

Production, Pricing and Quality Choice

Firms are indexed by their specific productivity level z. Producing higher quality goods requires higher marginal cost $mc_t(z)$:

$$mc_t(z) = \left(1 + \frac{q(z)^{\frac{1}{\phi}}}{z}\right)\frac{w_t}{Z_t z},$$

where ϕ $(0 \leq \phi < 1)$ is a parameter that determines the quality ladder in the economy. Provided demand function found previously firm z maximizes its profits by charging:

$$\rho_{D,t}(z) = \frac{\sigma}{\sigma - 1} mc_t(z), \tag{5}$$

And minimizing the quality-adjusted marginal cost $mc_t(z)/q(z)$,

$$q(z) = \left(\frac{\phi}{1-\phi} z\right)^{\phi}.$$

Provided $\phi > 0$, a highly productive firm produces high quality goods.

Profits and Export Decision

Profits (dividends) are given by

$$d_{D,t}(z) = \frac{1}{\sigma} N_{D,t}^{\psi(\omega-1)-1} \left(\frac{\rho_{D,t}(z)}{q(z)} \right)^{1-\omega} C_t,$$

If the firm exports, its export price is $\rho_{X,t}(a) = \tau_t \rho_{D,t}(z) Q_t^{-1}$. $\rho_{X,t}(z)$. τ_t is the iceberg trade cost. Only a subset of firms with a capability level z which is above the cutoff level $z_{X,t}$ exports by charging sufficiently lower quality-adjusted prices:

$$d_{X,t}(z) = \frac{Q_t}{\sigma} N_{X,t}^{\psi(\omega-1)-1} \left(\frac{\rho_{X,t}(z)}{q(z)} \right)^{1-\omega} C_t^* - \frac{w_t f_X}{Z_t}, \text{ if firm } z \text{ exports},$$

The cutoff firm for exporting and firm averages

The cutoff level $z_{X,t}$ producers earn just zero profits:

$$d_{X,t}\left(z_{X,t}\right)=\frac{Q_t}{\sigma}N_{X,t}^{\psi(\omega-1)-1}\left(\frac{\rho_{X,t}\left(z_{X,t}\right)}{q\left(z_{X,t}\right)}\right)^{1-\omega}C_t^*-\frac{w_t f_X}{Z_t}=0. \qquad (6)$$

We assume $G\left(z\right)$ is a Pareto distribution. Following Melitz (2003), we define two average firm specific productivity levels, $\widetilde{z}_D$ for domestically producing firms and $\widetilde{z}_{X,t}$ for exporters:

$$\widetilde{z}_D\equiv\left[\int_{z_{\min}}^{\infty}z^{\sigma-1}dG(z)\right]^{\frac{1}{\sigma-1}}, \qquad \widetilde{z}_{X,t}\equiv\left[\frac{1}{1-G(z_{X,t})}\int_{z_{X,t}}^{\infty}z^{\sigma-1}dG(z)\right]^{\frac{1}{\sigma-1}}.$$

Firm Entry and Exit

We assume that entrants at time t only start producing at time $t+1$. Entrants' expected post entry value is

$$\widetilde{v}_t^s = E_t \sum_{i=t+1}^{\infty} \beta^{i-t} \left(\frac{C_i}{C_t} \right)^{-\gamma} (1-\delta)^{s-t} \widetilde{d}_i^s$$

Entry occurs until the following free entry condition is satisfied:

$$\widetilde{v}_t^s = \frac{w_t}{Z_{E,t}} f_E . \tag{7}$$

The timing of entry and production we discussed implies that the number of domestically producing firms evolves according to
$N_{D,t} = (1-\delta)\left(N_{D,t-1} + N_{E,t-1}\right)$.

Household Budget Constraint and Intertemporal Choices

There are two types of financial assets, equities and bonds, each of which is held only domestically. These returns are

$$R^s_{h,t+1} \equiv (1-\delta)\frac{\widetilde{v}^s_{t+1}+\widetilde{d}^s_{t+1}}{\widetilde{v}^s_t}, \quad R^s_{f,t+1} \equiv (1-\delta)\frac{\widetilde{v}^{s*}_{t+1}+\widetilde{d}^{s*}_{t+1}}{\widetilde{v}^{s*}_t}\frac{Q_{t+1}}{Q_t}$$

$$R^b_{h,t+1} \equiv 1+r_{t+1}, \quad R^b_{f,t+1} \equiv (1+r^*_{t+1})\frac{Q_{t+1}}{Q_t}.$$

The budget constraint of a representative household is

$$\begin{aligned} C_t + \widetilde{v}^s_t\left(N_{D,t}+N_{E,t}\right)s_{h,t+1} + b_{h,t+1} \\ = w_t L_t + R^s_{h,t}\widetilde{v}^s_{t-1}\left(N_{D,t-1}+N_{E,t-1}\right)s_{h,t} + R^b_{h,t}b_{h,t} \end{aligned} \quad (8)$$

Optimal choice

The representative household maximizes the expected intertemporal utility with respect to $s_{h,t+1}$, $b_{h,t+1}$, L_t and C_t subject to (8) for all periods. As a result, Euler equations for share holdings can be derived as

$$1 = \beta E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} R^s_{h,t+1} \right],$$

Euler equations for bond holdings are given by

$$1 = \beta E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} R^b_{h,t+1} \right].$$

Finally, the optimal labor supply is given by

$$\chi \left(L_t \right)^{\frac{1}{\psi}} = w_t C_t^{-\gamma}.$$

Supplied labor units L_t are demanded for fixed costs of exporting and firm creation as well as for the production of domestic and tradable goods. This implies that

$$L_t = \frac{N_{E,t}\widetilde{v}_t^s}{w_t} + \frac{(\sigma - 1)\, N_{D,t}\widetilde{d}_t}{w_t} + \frac{\sigma N_{X,t} f_X}{Z_t}.$$

The model is completed by considering the balanced trade condition such that

$$\int_0^{N_{X,t}^*} p_{X,t}^*\left(\vartheta^*\right) c_{X,t}\left(\vartheta^*\right) d\vartheta^* = \int_0^{N_{X,t}} p_{X,t}\left(\vartheta\right) c_{X,t}^*\left(\vartheta\right) d\vartheta.$$

Choice of parameters' values

Table: Baseline parameter values

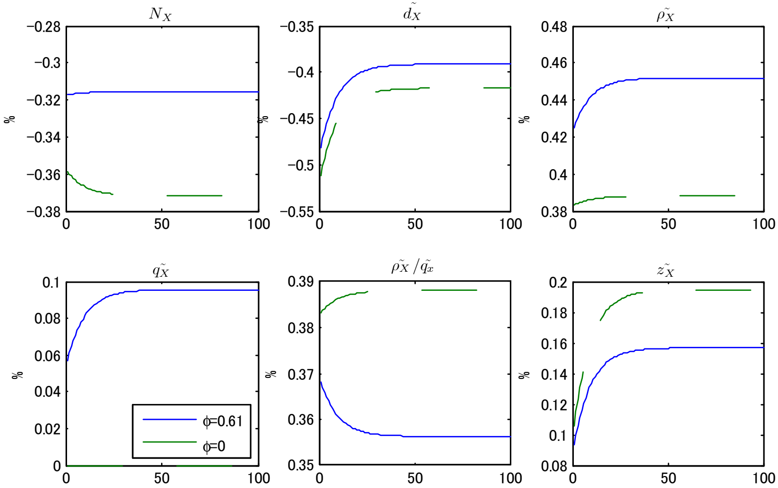
γ	constant risk aversion	2
β	discount factor	0.99
φ	Frisch elasticity of labor supply	2
σ	elasticity of substitution among varieties	3.8
ω	between Home and Foreign goods	3.8
τ	steady state trade cost	1.3
δ	death shock	0.025
k	Pareto distribution	3.34
ψ	Preference for variety	Dixit-Stiglitz
ϕ	quality ladder	0.61

Productivity shock process

For simplicity, the shocks on marginal costs of production Z_t and firm creation $Z_{E,t}$ are assumed to be perfectly correlated such that $Z_t = Z_{E,t}$ and $Z_t^* = Z_{E,t}^*$. These processes are selected from Backus et al. (2012), such that $\mathrm{Z}_{t+1} = \dot{}\mathrm{Z}_t + \xi_t$, where $\mathrm{Z}_t = \begin{bmatrix} Z_t, & Z_t^* \end{bmatrix}'$, $\xi_t = \begin{bmatrix} \xi_t, & \xi_t^* \end{bmatrix}'$ and the correlation of shocks and error terms are given by

$$\Omega = \begin{bmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{bmatrix}, \text{ and } V(\xi) = \begin{bmatrix} 0.73 & 0.19 \\ 0.19 & 0.73 \end{bmatrix}.$$

Permanent rise in trade cost



Permanent rise in trade cost

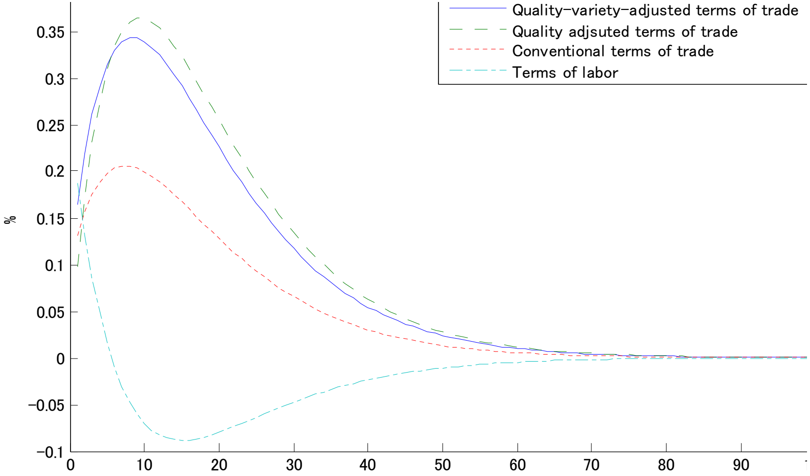
- The average real unit price of exporting goods $\widetilde{\rho}_{X,t}$ increases more for the benchmark model with quality ladder.
- This is consistent with the (contradictory) empirical findings in trade literature: the more difficult to export, the higher is the exporting price.
- In order to attract the demand, charging higher price is possible due to higher quality $\widetilde{q}_{X,t}$ and lower quality adjusted price $\widetilde{\rho}_{X,t}/\widetilde{q}_{X,t}$.

In welfare basis, the terms of trade (defined as the relative price of the basket of imported goods) fluctuations incorporate those in product quality and the number of exporting (imported) varieties as

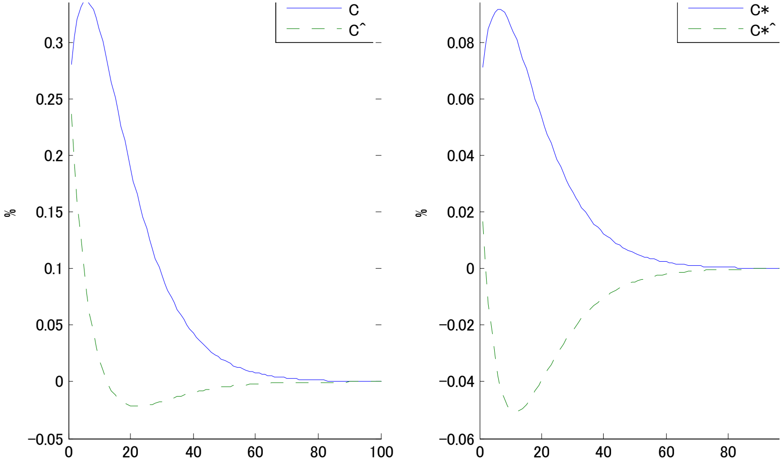
$$\mathrm{TOT} = \mathrm{P}_F - \mathrm{P}_H^* = \underbrace{\overbrace{\widetilde{\mathrm{p}}_X^* - \widetilde{\mathrm{p}}_X}^{\widehat{\mathrm{TOT}}} + \widetilde{\mathrm{q}}_X^R}_{\mathrm{TOT}^q} + \psi \mathrm{N}_X^R .$$

where TOT is the quality-variety-adjusted terms of trade and TOT^q is the quality-adjusted terms of trade. $\widehat{\mathrm{TOT}}$ is the conventional terms of trade which is further decomposed as $\widehat{\mathrm{TOT}} = \mathrm{TOL} + \widetilde{\mathrm{z}}_X^R$ where $\mathrm{TOL} = -\left(\mathrm{w}^R - \mathrm{Z}^R\right)$ is the terms of labor. And the relative number of varieties and quality are $\mathrm{N}_X^R = \mathrm{N}_X - \mathrm{N}_X^*$, $\widetilde{\mathrm{q}}_X^R = \widetilde{\mathrm{q}}_X - \widetilde{\mathrm{q}}_X^*$.

International transmission of a positive productivity shock



Welfare



C
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−0.02
−0.04
−0.06
0
20
40
60
80

The Backus-Smith puzzle revisited

Under complete asset markets, the marginal utility stemming from one unit of nominal wealth must be equal across countries:

$$U_{C,t} = U_{C^*,t} Q_t$$

Using our specification of preference and taking the first-order fluctuations, we have

$$\mathrm{C} - \mathrm{C}^* = \frac{1}{\gamma}\mathrm{Q} \tag{9}$$

Since $\gamma \geq 1$, a higher consumption in Home must be associated with a real depreciation. But this is *not* observed in the data (for instance, the average correlation with US and other OECD countries is -0.17).

Several competing recipes in resolving the puzzle...

- Under complete markets
  ->introduce preference shocks that breaks the tight link between relative consumption and the real exchange rate.
- Under incomplete markets
  ->introduce *the wealth effect* that brings the real exchange rate into an appreciation following a positive productivity shock, i.e. low elasticity of substitution and higher persistence of shock (Corsetti et al. 2008), higher number of varieties (Hamano 2013)

The mechanism of the paper is classed in the second type. The wealth effect is driven by higher product quality. Impact from the variety is mitigated with heterogenous firms.

The welfare consistent BS relation under the balanced trade

With the balanced trade condition, we have

$$\mathrm{C} - \mathrm{C}^{*} = \frac{2S_{ED}\omega - 1}{2S_{ED} - 1}\mathrm{Q} + \frac{(\omega - 1)\, S_{ED}}{2S_{ED} - 1}\left[\psi(\mathrm{N}_D^R - \mathrm{N}_X^R) + \widetilde{\mathrm{z}}_X^R + \widetilde{\mathrm{q}}_X^R\right] \quad (10)$$

Proposition: The equilibrium allocation under the financial autarky that allows changes in product quality and the number of varieties mimics perfectly that obtained with complete asset markets when $\omega = \gamma = 1$. This is the reestablishment of Cole and Obstfeld (1991)'s result with product quality and variety.

The real exchange rate in empirical basis

Note that the welfare consistent fluctuation in Q include those imperfectly observed fluctuations in product quality and the number of varieties:

$$\begin{aligned}\widehat{\mathsf{Q}} = \mathsf{Q} - \psi\lambda_1 \mathsf{N}_D^R + \psi\lambda_2 \mathsf{N}_X^R + \lambda_3 \widetilde{\mathsf{q}}_X^R \\ = (2S_{ED} - 1)\,\mathsf{TOL} - (1 - S_{ED})\,\widetilde{\mathsf{z}}_X^R \\ + \psi(S_{ED} - \lambda_1)\mathsf{N}_D^R - \psi\,(1 - S_{ED} - \lambda_2)\,\mathsf{N}_X^R - (1 - S_{ED} - \lambda_3)\,\widetilde{\mathsf{q}}_X^R \qquad (11)\end{aligned}$$

where λ_1, λ_2 and λ_3 represent the degree of inefficiency of statistical agents. When $\lambda_1 = \lambda_2 = \lambda_3 = 0$, there are no discrepancy. When $\lambda_1 = S_{ED}$ and $\lambda_2 = \lambda_3 = 1 - S_{ED}$, the statistical agency completely ignore fluctuations in the number of varieties and the product quality. When $\lambda_1 = \lambda_2 = \lambda_3 = 1$, this is a similar definition argued in Feenstra (1994) and Ghironi and Melitz (2005).

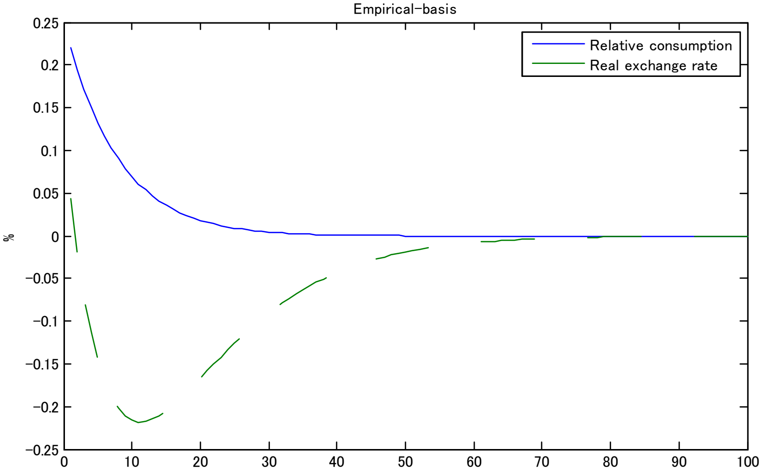
The observable BS relation under the balanced trade

With the previously mentioned empirical based fluctuations, we can rewrite

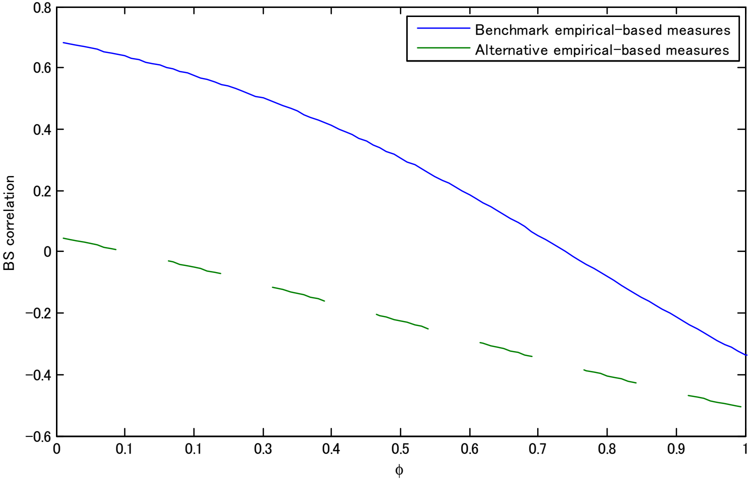
$$\widehat{\mathrm{C}} - \widehat{\mathrm{C}}^{*} = \frac{2S_{ED}\omega - 1}{2S_{ED} - 1}\widehat{\mathrm{Q}} + \frac{\psi\left(2\lambda_{1} - 1\right)\left(\omega - 1\right)S_{ED}}{2S_{ED} - 1}\mathrm{N}_{D}^{R} -$$
$$\frac{\psi\left(2\lambda_{2} - 1\right)\left(\omega - 1\right)S_{ED}}{2S_{ED} - 1}\mathrm{N}_{X}^{R} - \frac{\left(2\lambda_{3} - 1\right)\left(\omega - 1\right)S_{ED}}{2S_{ED} - 1}\widetilde{\mathrm{q}}_{X}^{R} + \frac{\left(\omega - 1\right)S_{ED}}{2S_{ED} - 1}\widetilde{\mathrm{z}}_{X}^{R}$$

The first term is basically the same term argued in Corsetti et al. (2008) in the absence of changes in the number of product varieties and quality. The observable correlation between cross country difference in consumption and the real exchange rate fluctuations is *conditional* on unobservable changes in quality and variety.

Real exchange rate and relative consumption (Corr=0.16)



Quality ladder and the BS correlation



The Backus-Smith Correlation with Data

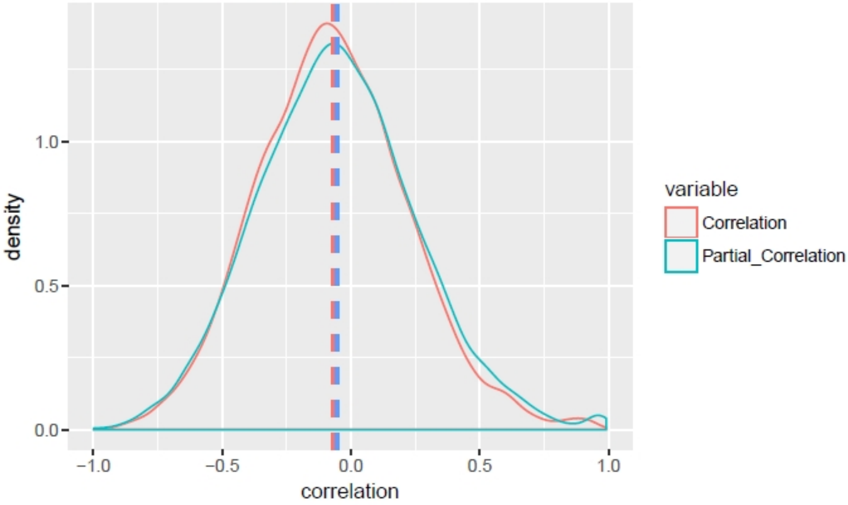
Feenstra and Romalis (2014) provide a data set of their estimates of quality of export and import for each good (defined in four digit sitc code) for each country for each year (from 1984 to 2011). Based on their estimates, I compute the aggregate quality of a specific country in a given year as

$$q_t^i = \sum_{j \in J_t^i} ts_{jt}^i q_{jt}^i,$$

Consumption growth and real exchange rate fluctuations come from the latest Penn World Table. Definition of "income group" follow that of the World Bank.

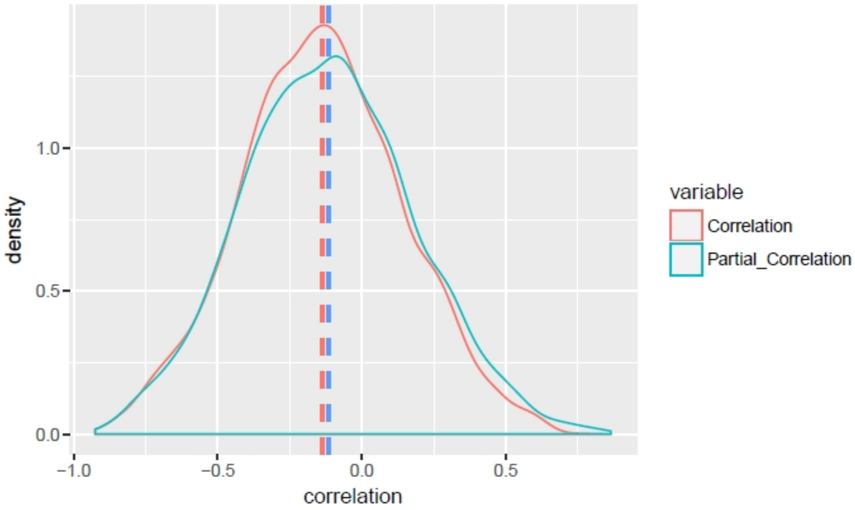
Unconditional vs. Conditional Correlation: Imports

Figure A.1: Full Sample Import



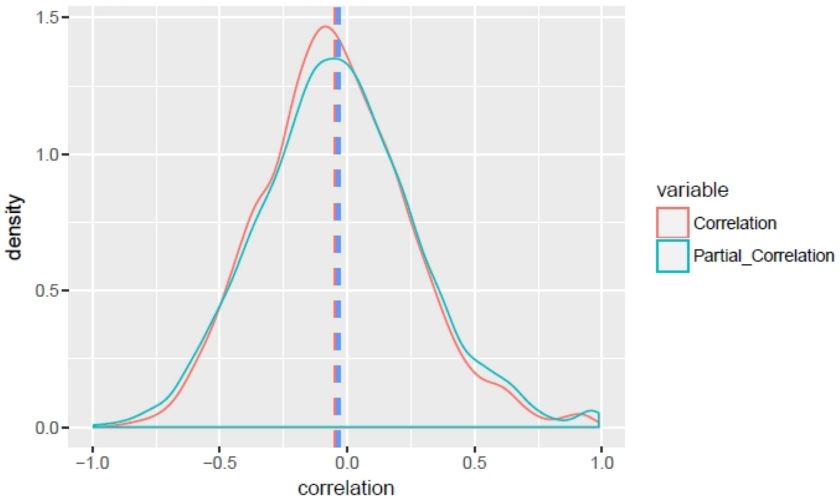
Unconditional vs. Conditional Correlation: Imports

Figure A.2: High and Upper Middle Income Group Import



Unconditional vs. Conditional Correlation: Imports

Figure A.3: High and Upper Middle vs. Low and Lower Middle Group Import



Unconditional vs. Conditional Correlation: Imports

Imports	Unconditional	Conditional	t-value	Nb obs
Full Sample	−0.0685	−0.0526	−4.003****	11459
High Income Group	−0.1440	−0.0957	−4.021****	1231
High and Upper Middle Income Group	−0.1378	−0.1154	−3.516***	4115
Low Income Group	−0.0046	0.0185	−1.195	269
Low and Lower Middle Income Group	0.0449	0.0513	−0.641	1792
High vs Low Income	−0.0958	−0.0713	−2.396*	1185
High and Upper Middle vs. Low and Lower Middle	−0.0451	−0.0346	−1.817	5445

[a]

[a] ns $P > 0.05$ * $P \leq 0.05$ ** $P \leq 0.01$ *** $P \leq 0.001$ **** $P \leq 0.0001$

Unconditional vs. Conditional Correlation: Exports

Exports	Unconditional	Conditional	t-value	Nb obs
Full Sample	−0.0688	−0.0489	−4.973****	11451
High Income Group	−0.1454	−0.0977	−3.890***	1212
High and Upper Middle Income Group	−0.1383	−0.1036	−5.353****	4070
Low Income Group	−0.0046	0.0069	−0.593	269
Low and Lower Middle Income Group	0.0439	0.0530	−0.917	1784
High vs Low Income	−0.0952	−0.0667	−2.729**	1172
High and Upper Middle vs. Low and Lower Middle	−0.0447	−0.0318	−2.220*	5394

[a]

[a] ns $P > 0.05$ * $P \leq 0.05$ ** $P \leq 0.01$ *** $P \leq 0.001$ **** $P \leq 0.0001$

Conclusion

- Considering international transmission via changes in product quality and the number of varieties is important both qualitatively and quantitatively.
- Wealth effect driven by product quality upgrading would be a key in resolving the BS puzzle.
- Supportive evidence: the BS correlation which is conditional on changes in quality and variety tends to be closer to the complete market allocation.
- What is striking is heterogeneity across different income groups. Risk sharing is "missing" among high income and upper middle income country group. Among low income and lower middle income country group, "missing risk sharing" is missing, no welfare transmission through quality and variety. Across different income group, we detect relatively weak transmission through quality and variety.