Unobservable Skill Dispersion and Comparative Advantage Online Appendix

Matilde Bombardini*, Giovanni Gallipoli† and Germán Pupato‡

October 2013

Abstract

This appendix contains details of the numerical implementation for the quantitative exercise in Section 7 of the paper and additional empirical results.

1 Numerical Implementation

In what follows we describe how we parameterize the model and how we solve for an equilibrium.

Preference shares. We assume that preferences are homogeneous across countries. To measure these shares we proceed in three steps: first, we use OECD-STAN data to approximate, for each country, the relative share of consumption in each of the 63 goods (industries). Second, we average each industry's shares across countries and obtain a common set of 63 values for $\alpha(\lambda)$. To simulate trade flows we need the preference share for the non-differentiated good (i.e., the good produced by the industry in which $\lambda = 1$ and there are no transport costs). This latter sector is only added for convenience in the model and cannot be related to a direct data counterpart. The (unobserved) consumption share of the non-differentiated good (the one produced by the industry in which $\lambda = 1$) can be obtained as a by-product of the general equilibrium solution and we set it at the lowest value which guarantees: (1) trade equilibrium, with no deficits or surpluses; (2) incomplete specialization.[1]

*University of British Columbia, CIFAR and NBER.
†University of British Columbia and RCEA.
‡Ryerson University.

[1] Note that we set this share to the lowest possible value such that there is imperfect specialization in both benchmark calibration and experiments.

In what follows we provide some details about the individual steps. As we mentioned, the first step is to use OECD-STAN data to derive country-specific preference shares in each industry λ. We denote the expenditure share spent on each differentiated good λ by country j as $\alpha_j(\lambda)$ and compute it as follows:

$$\alpha_j(\lambda) = \frac{x_{jj}(\lambda) + \sum_{c\neq j} x_{cj}(\lambda)}{\sum_{\lambda}\left[x_{jj}(\lambda) + \sum_{c\neq j} x_{cj}(\lambda)\right]}$$

where $x_{jj}(\lambda)$ is the consumption of good λ produced in j. In turn $x_{jj}(\lambda)$ is calculated as:

$$x_{jj}(\lambda) = \left(\frac{1}{IPR_j(\lambda)} - 1\right)\sum_{c\neq j} x_{cj}(\lambda)$$

where $IPR_j(\lambda) = \frac{IMP_j(\lambda)}{PROD_j(\lambda)+IMP_j(\lambda)-EXP_j(\lambda)}$. Data on production $PROD_j(\lambda)$, imports $IMP_j(\lambda)$ and exports $EXP_j(\lambda)$ is from the OECD-STAN database. Whenever import penetration ratios (IPR) are not between zero and one, we replace them with their average across sectors for the same country.

Then, for each industry j we average across countries, weighing by population. This results in 63 different values (a set $\{\alpha(\lambda)\}$ for $\lambda = 1, 2, ..., 63$) which we use as the common preference shares in all countries.

Estimating the preference share parameter for the non-differentiated (residual) good (the industry with no trade costs and $\lambda = 1$) requires an extra step because there is no data which can be used to measure the share of consumption in this industry. In what follows we superimpose the symbol "~" to a model variable if it indicates its observed data value. We use the fact that, by definition,

$$\alpha^c_{\lambda=1} = \frac{\sum\limits_j x_{jc}(\lambda=1)}{\tilde{E}^c}$$

Clearly we cannot observe $\sum\limits_j x_{jc}(1)$ from data. However we can derive it using the following equilibrium conditions,

$$W\tilde{L}^c = \sum_j x_{cj}(\lambda=1) + \sum_{\lambda\neq 1}\sum_j \tilde{x}_{cj}(\lambda) \quad (1)$$

$$\sum_j x_{cj}(\lambda=1) + \sum_{\lambda\neq 1}\sum_j \tilde{x}_{cj}(\lambda) = \sum_j x_{jc}(\lambda=1) + \sum_{\lambda\neq 1}\sum_j \tilde{x}_{jc}(\lambda) \quad (2)$$

From equation 1 it is possible to see that, given some W_1, we can identify $\sum\limits_j x_{cj}(\lambda=1)$; this can be used, in turn, in equation 2 to obtain an estimate of $\sum_j x_{jc}(\lambda = 1)$. As discussed in the paper, W is constant across countries in equilibrium. Moreover there are infinitely many triplets of W, $\sum_j x_{cj}(\lambda = 1)$ and $\sum_j x_{jc}(\lambda = 1)$ which satisfy equations $(1, 2)$. We pick the W which guarantees incomplete specialization in the benchmark equilibrium. More specifically, suppose that country c^* has the largest observed exports per worker in the differentiated goods sector (that is, the highest value $\sum_{\lambda \neq 1} \sum_j \tilde{x}_{c^* j}(\lambda)/\tilde{L}^{c^*}$). Then, we assume that $W = \sum_{\lambda \neq 1} \sum_j \tilde{x}_{c^* j}(\lambda)/\tilde{L}^{c^*}$, meaning that country c^* only produces an infinitely small amount of output in industry $\lambda = 1$. Since W is constant across countries, we can recover $\sum_j x_{cj}(\lambda = 1)$ for all the other countries using equation (1) and then verify that none of them is less or equal zero. In this way we also derive, using (2) for each country, the value of $\sum_j x_{jc}(\lambda = 1)$ and, given $\tilde{E}^c$, we can estimate $\alpha^c_{\lambda=1}$. Finally we average out these estimates to compute the common, economy-wide $\alpha_{\lambda=1}$, which is used to simulate the economy. Note that the 63 α_j for the differentiated goods' sectors are rescaled by $(1 - \alpha_{\lambda=1})$, so that $\sum_{j=1}^{63} \frac{\alpha_j}{(1-\alpha_{\lambda=1})} + \alpha_{\lambda=1} = 1$.

Transport (residual) costs. The transport cost capture all residual heterogeneity underlying observed trade flows. We obtain estimates of the $\tau_{cj}(\lambda)$ values in two steps: first, we use the fact that any ratio of transport costs in the differentiated goods' sectors can be expressed as a function of observed bilateral trade flows; that is,

$$\frac{\tilde{x}_{jj}(\lambda)}{\tilde{x}_{cj}(\lambda)} = \frac{\tau_{jj}(\lambda)^{-\theta}}{\tau_{cj}(\lambda)^{-\theta}} = \frac{1}{\tau_{cj}(\lambda)^{-\theta}}$$

where the transportation cost of any country j to itself, $\tau_{jj}(\lambda)$, is normalized to one. Therefore, one can recover the transportation costs of any country pair in a given industry by solving $\tau_{cj}(\lambda) = \left(\frac{\tilde{x}_{jj}(\lambda)}{\tilde{x}_{cj}(\lambda)}\right)^{\frac{1}{\theta}}$, where the right hand side values are taken from data.[2] The estimated transport costs serve the purpose of a model residual, capturing any remaining source of trade flow variations which cannot be explained by the explicitly modeled sources of comparative advantage.

Once we have recovered transport costs for all country-pairs and industries, we decompose them into: (i) a common country pair component τ_{cj} (equal for all industries) and (ii) a country-industry specific term $\tau_j(\lambda)$. We do this by estimating the non-parametric regression,

$$\log \tau_{cj}(\lambda) = \phi_{cj} + \varphi_{j\lambda} + u_{cj\lambda}$$

This decomposition guarantees that transport costs do not generate comparative advantage.

[2] Whenever observed trade flows are zero, we set them to be a tiny positive value.

The τ's we employ in the counterfactual are the fitted values of the above regression, namely. $\widehat{\tau}_{cj}(\lambda) = \exp(\widehat{\phi}_{cj} + \widehat{\varphi}_{j\lambda})$.

Fundamental Productivities. The value of $A(\lambda, c)$ for each country-industry pair is approximated using the equation $A(\lambda, c) = \left(\int a^{\lambda} g(a, c) da\right)^{\frac{\gamma}{\lambda}}$ where a denotes the skill level of a worker, measured by the IALS scores. The mean skill level is normalized to one in all countries to eliminate comparative advantage due to average skills, and $g(a, c)$ denotes the skill distribution of country c. The discrete version of this proxy is $A(\lambda, c) = (\sum\limits_{a \in \Lambda} a^{\lambda} w(a, c))^{\frac{\gamma}{\lambda}}$, where Λ denotes the set of possible values a can take in the data and $w(a, c)$ denotes the weight of workers with skill level a in country c.

Computing equilibria and counterfactual analysis. Once we have set values for all $\tau_{cj}(\lambda)$, $A(\lambda, c)$ and preference shares α_{λ}, we solve for the benchmark economy equilibrium. Assuming we know the total expenditure of country j, E_j, the simulated bilateral trade flows in the 63 differentiated goods' sectors $x_{cj}(\lambda)$ are given by,

$$x_{cj}(\lambda) = \frac{[\tau_{cj}/A(\lambda, c)]^{-\theta}}{\sum\limits_{c'} [\tau_{c'j}/A(\lambda, c')]^{-\theta}} \alpha(\lambda)(1 - \alpha_{\lambda=1}) E_j \tag{3}$$

Similarly, imports and exports in the residual industry (non-differentiated goods' sector with $\lambda = 1$) can be calculated using, respectively, the condition $\sum\limits_{j} x_{jc}(\lambda = 1) = \alpha_{\lambda=1} E_c$ and the trade balance condition in equation (2). With these simulated trade flows in hand, the equilibrium wage W must be such that, for each country, the following holds

$$W \tilde{L}^{c} = \sum_{j} x_{cj}(\lambda = 1) + \sum_{\lambda \neq 1} \sum_{j} x_{cj}(\lambda)$$

The question is: how can we derive a set of country-specific expenditures E_c such that the above conditions are not violated? It turns out that in our simple model the relative expenditures are trivially pinned down by

$$\frac{\tilde{L}_1}{\tilde{L}_c} = \frac{\sum\limits_{j} x_{1j}(\lambda = 1) + \sum\limits_{\lambda \neq 1} \sum\limits_{j} x_{1j}(\lambda)}{\sum\limits_{j} x_{cj}(\lambda = 1) + \sum\limits_{\lambda \neq 1} \sum\limits_{j} x_{cj}(\lambda)} = \frac{E_1}{E_c}$$

In our implementation we proxy the total employment ratio between two countries by the countries' population ratio.[3] Normalizing $E_1 = 1$, we have that $E_c = \frac{\tilde{L}_c}{\tilde{L}_1}$.

[3] Results do not change if we use total workforces.

In the counterfactual analysis, we simply change $A(\lambda, c)$ while keeping transport costs and preference parameters unchanged. Then, counterfactual bilateral trade flows $x_{cj}(\lambda)$ can be computed, as long as E_j is known, using equation (3) and a new equilibrium can be computed again, exactly in the way described above. This gives a counterfactual wage W_{cf}. However, to compare the change in bilateral trade flows we assume that the wage in the benchmark and counterfactual economies are the same. This can be done easily: since trade flows and wages are linear in the expenditure E, we renormalize the countries expenditures E by a factor of $\frac{W}{W_{cf}}$ so that wages are equalized in the benchmark and counterfactual equilibria.

2 Quantitative Analysis: Additional Results

As we mentioned in Section 7, we experiment with alternative parameterizations of the production technologies. Every time we re-parameterize production technologies we solve for a new equilibrium, and obtain a new set of trade costs which match trade flows. In what follows we report technology estimates as well as results of counterfactual experiments under alternative parametrizations.

To pinpoint the values of γ and the λs we use the model restriction $\frac{w_\lambda h}{py} = \frac{\gamma}{\lambda}$. For each industry we use data on total compensation (or, alternatively, annual payroll) from the 2002 US Economic Census and divide them by value added to approximate $\frac{w_\lambda h}{py}$ and, hence, the ratio $\frac{\gamma}{\lambda}$. However these ratios do not allow us to estimate the value of γ and of all 63 λ's. To obtain these parameter estimates we proceed by setting γ to alternative values and then invert the $\frac{\gamma}{\lambda}$ ratios to get the associated λs. We experiment with three different values of γ: 0.3, 0.5 and 0.7. These values guarantee that all industries have convex isoquants. Estimates of the associated λs are presented in Table 1, using the total compensation proxy for the wage bill. When we set $\gamma = 0.3$ we get substantially lower values for the λs, with a value larger than one only in 14 out of 63 industries; when $\gamma = 0.7$ all the industries have $\lambda > 1$, an admittedly extreme assumption which however helps us provide an upper bound for the changes in trade flows.

Table 1: Estimates of industry-specific λ values under alternative normalizations of γ

industry	$\gamma = 0.3$	$\gamma = 0.5$	$\gamma = 0.7$
Agricultural chemical mfr.	1.43	2.38	3.33
Agricultural implement, construction, mining and oil field machinery mfr.	0.68	1.13	1.58
Aircraft, aerospace prod. and parts mfr.	0.62	1.03	1.44
Aluminum production and processing	0.66	1.09	1.53
Animal food, grain and oilseed milling	1.58	2.64	3.69

Animal slaughtering and processing	0.77	1.28	1.80
Apparel accessories and other apparel mfr.	0.55	0.91	1.28
Bakeries	0.80	1.33	1.87
Beverage mfr.	1.37	2.28	3.20
Cement, concrete, lime, and gypsum product mfr.	0.75	1.24	1.74
Commercial and service industry machinery mfr.	0.67	1.11	1.55
Communications, audio, and video equipment mfr.	0.79	1.31	1.83
Computer and peripheral equipment mfr.	1.04	1.74	2.43
Cut and sew apparel mfr.	0.78	1.30	1.83
Cutlery and hand tool mfr.	0.77	1.28	1.79
Dairy product mfr.	1.05	1.76	2.46
Electrical lighting, equipment, and supplies mfr., n.e.c.	0.69	1.15	1.60
Electronic component and product mfr., n.e.c.	0.87	1.45	2.04
Engines, turbines, and power transmission equipment mfr.	0.97	1.62	2.27
Fabric Mills	0.59	0.98	1.37
Fiber, yarn, and thread mills	0.51	0.85	1.19
Footwear mfr.	0.56	0.93	1.30
Foundries	0.52	0.87	1.22
Fruit and vegetable preserving and specialty food mfr.	1.26	2.11	2.95
Furniture and related product mfr.	0.62	1.03	1.44
Glass and glass product mfr.	0.66	1.11	1.55
Household appliance mfr.	0.74	1.24	1.73
Industrial and miscellaneous chemicals	0.94	1.57	2.20
Iron and steel mills and steel product mfr.	0.61	1.02	1.43
Leather tanning and prod., except footwear mfr.	0.69	1.15	1.61
Machine shops; turned product; screw, nut and bolt mfr.	0.53	0.88	1.23
Machinery mfr., n.e.c.	0.58	0.97	1.35
Medical equipment and supplies mfr.	0.80	1.33	1.86
Metalworking machinery mfr.	0.48	0.79	1.11
Miscellaneous nonmetallic mineral product mfr.	0.78	1.30	1.82
Motor vehicles and motor vehicle equipment mfr.	0.73	1.22	1.71
Navigational, measuring, electromedical, and control instruments mfr.	0.58	0.98	1.37
Nonferrous metal, except aluminum, production and processing	0.63	1.05	1.47

Ordnance and miscellaneous fabricated metal prod. mfr.	0.65	1.08	1.51
Other transportation equipment mfr.	0.84	1.40	1.96
Paint, coating, and adhesive mfr. B46	1.04	1.74	2.43
Paperboard containers, boxes misc. paper and pulp prod.	0.70	1.17	1.64
Petroleum and Coal prod. mfr.	1.35	2.24	3.14
Pharmaceutical and medicine mfr.	1.78	2.97	4.16
Plastics product mfr.	0.70	1.17	1.64
Pottery, ceramics, structural clay and related prod. mfr.	0.63	1.05	1.47
Prefabricated wood buildings, mobile homes and miscellaneous wood prod.	0.54	0.90	1.25
Printing and related support activities	0.58	0.97	1.36
Pulp, paper, and paperboard mills	0.99	1.65	2.31
Railroad rolling stock mfr.	0.72	1.20	1.68
Resin, synthetic rubber and fibers, and filaments mfr.	1.02	1.71	2.39
Rubber prod.	0.55	0.91	1.28
Sawmills and wood preservation	0.53	0.88	1.24
Seafood and other miscellaneous foods, n.e.c.	1.44	2.40	3.36
Ship and boat building	0.56	0.94	1.31
Soap, cleaning compound, and cosmetics mfr.	1.96	3.27	4.58
Structural metals, and tank and shipping container mfr.	0.60	0.99	1.39
Sugar and confectionery prod.	1.15	1.92	2.69
Textile and fabric finishing and coating mills	0.69	1.15	1.61
Textile product mills	0.69	1.15	1.60
Tobacco mfr.	5.27	8.78	12.30
Toys, amusement, sporting goods and miscellaneous mfr., n.e.c.	0.65	1.09	1.52
Veneer, plywood, and engineered wood prod.	0.53	0.88	1.24

We have solved for alternative benchmark equilibria and studied the counterfactuals for all the technology parameterizations described above. We report the results for technology estimates where we set γ to either 0.3 or 0.7.[4] Figure 1 reports changes in trade flows by industry (ordered in terms of increasing substitutability) using all 18 reference countries. The patterns confirm the findings discussed in the main body of the paper, although the magnitude of the changes tends to be smaller, with most of them being in the 1% range. When we instead simulate the model using

[4]We present results based on wage bills measured through total compensation. Available from the authors are several additional results based on wage bills measured from payroll data.

technology estimates associated to the normalization $\gamma = 0.7$ we obtain larger changes in trade flows, as shown in Figure 2.

Finally, for comparison, in Figures 3 and 4 we separately report the estimated changes in trade flows using as reference country only Germany and the US, under technology parameterizations with, respectively, $\gamma = 0.3$ or $\gamma = 0.7$. It is apparent that the patterns of change are identical, and the main difference is that $\gamma = 0.7$ implies larger effects, suggesting that the estimates of the effects of skill dispersion on trade patterns presented in the main body of the paper are fairly conservative.

Table 2: Changes in trade flows (wage: $\gamma = 0.3$)

country	exports			imports		
	(1)	(2)	(3)	(4)	(5)	(6)
	average	10%	90%	average	10%	90%
DNK	0.47	-0.63	0.74	0.23	0.31	-0.21
NLD	0.46	-0.59	0.54	0.28	0.42	-0.39
NOR	0.27	-0.42	0.25	0.15	0.25	-0.23
FIN	0.24	-0.31	0.33	0.15	0.23	-0.20
DEU	0.51	-0.60	0.70	0.38	0.56	-0.48
SWE	0.23	-0.23	0.25	0.09	0.18	-0.14
CZE	0.28	-0.10	0.65	0.07	0.10	-0.08
BEL	0.07	-0.03	0.01	0.06	-0.04	0.08
HUN	0.11	0.02	0.31	0.01	-0.02	0.02
CHE	0.09	0.09	-0.11	0.08	-0.14	0.12
CAN	0.32	-0.44	0.37	0.24	0.45	-0.37
NZL	0.08	-0.09	0.08	0.06	0.03	-0.06
IRL	0.10	0.00	-0.06	0.04	0.06	-0.04
UK	0.35	0.59	-0.41	0.35	-0.52	0.45
USA	0.31	0.38	-0.37	0.33	-0.44	0.40
ITA	0.43	0.65	-0.38	0.60	-0.76	0.70
SVN	0.85	1.06	-0.84	0.49	-0.87	0.65
POL	1.44	1.91	-1.56	1.12	-1.84	1.29

Notes:

- Columns (1) and (3) report the average of absolute percentage changes in trade; columns (2), (4), (5) and (6) report raw (not absolute) percentage changes in trade for the industries corresponding to the 10^{th} and 90^{th} percentile in the distribution of estimated λ's (skill substitutability).
- The countries are ranked by skill dispersion.
- 10^{th} percentile and 90^{th} percentile are the 6th and 58th industries ranked by λ's.

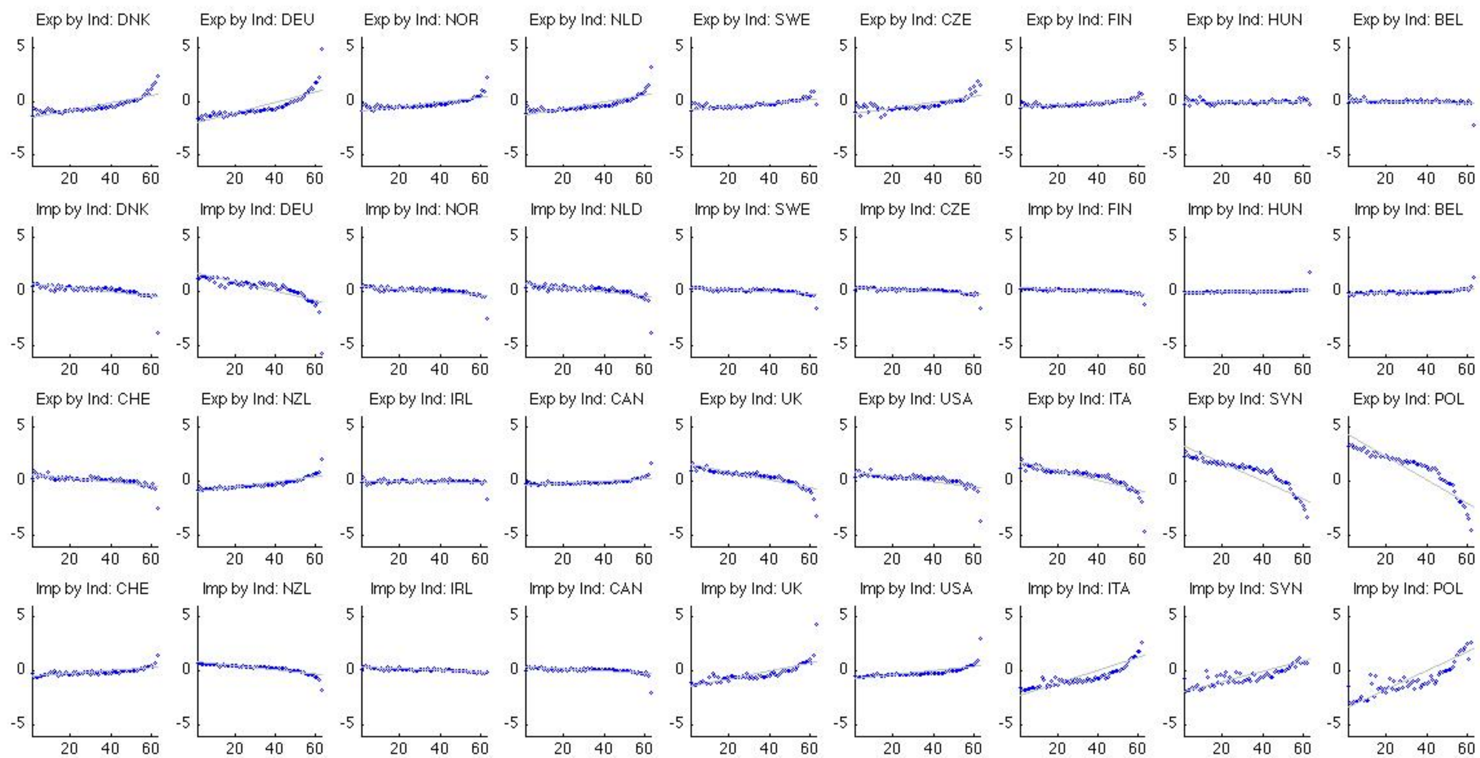
Table 3: Changes in trade flows (wage: $\gamma = 0.7$)

country	exports			imports		
	(1)	(2)	(3)	(4)	(5)	(6)
	average	10%	90%	average	10%	90%
DNK	2.85	0.70	8.88	1.41	-0.34	-2.45
NLD	2.78	0.64	6.17	1.65	-0.45	-4.25
NOR	2.00	0.46	3.08	1.09	-0.28	-2.78
FIN	1.58	0.35	3.99	1.10	-0.26	-2.42
DEU	3.17	0.65	8.13	2.29	-0.59	-5.15
SWE	1.52	0.24	2.48	0.78	-0.17	-1.10
CZE	1.77	0.11	7.68	0.54	-0.10	-1.03
BEL	0.41	0.05	0.65	0.31	0.04	0.57
HUN	0.57	-0.04	3.51	0.15	0.04	0.23
CHE	0.40	-0.11	-1.18	0.53	0.17	1.33
CAN	1.84	0.50	4.01	1.30	-0.51	-3.95
NZL	1.13	0.10	1.33	0.85	-0.07	-1.41
IRL	0.82	-0.04	-1.17	0.23	-0.04	0.17
UK	1.51	-0.58	-3.64	1.63	0.53	4.27
USA	1.82	-0.47	-4.47	1.81	0.52	4.81
ITA	2.87	-0.74	-4.65	4.92	0.88	8.77
SVN	4.44	-1.16	-9.06	2.13	0.98	7.49
POL	7.30	-2.03	-15.75	6.58	2.03	14.74

Notes:

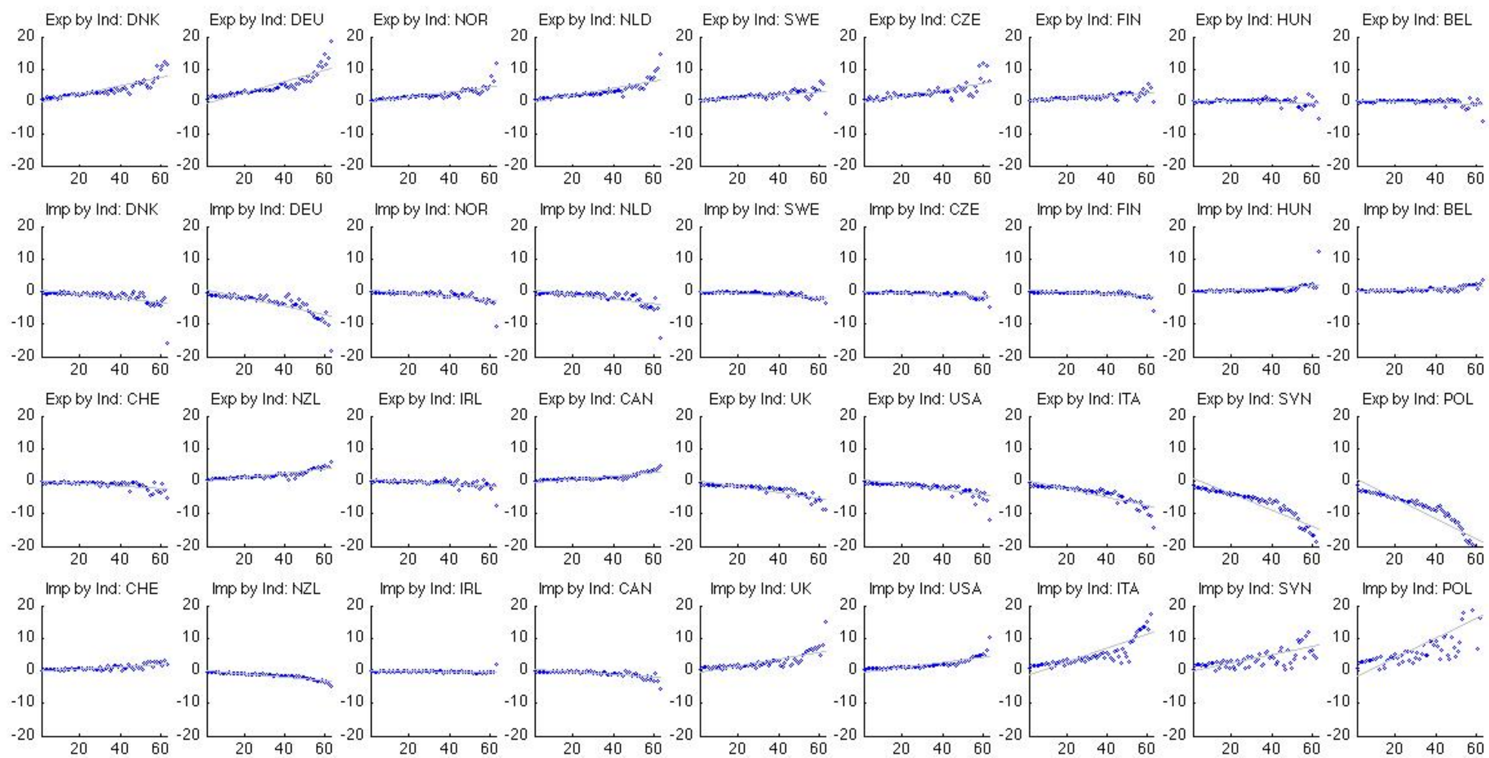
- Columns (1) and (3) report the average of absolute percentage changes in trade; columns (2), (4), (5) and (6) report raw (not absolute) percentage changes in trade for the industries corresponding to the 10^{th} and 90^{th} percentile in the distribution of estimated λ's (skill substitutability).
- The countries are ranked by skill dispersion.
- 10^{th} percentile and 90^{th} percentile are the 6th and 58th industries ranked by λ's.

Figure 1: Changes in trade flows across industries: $\gamma = 0.3$



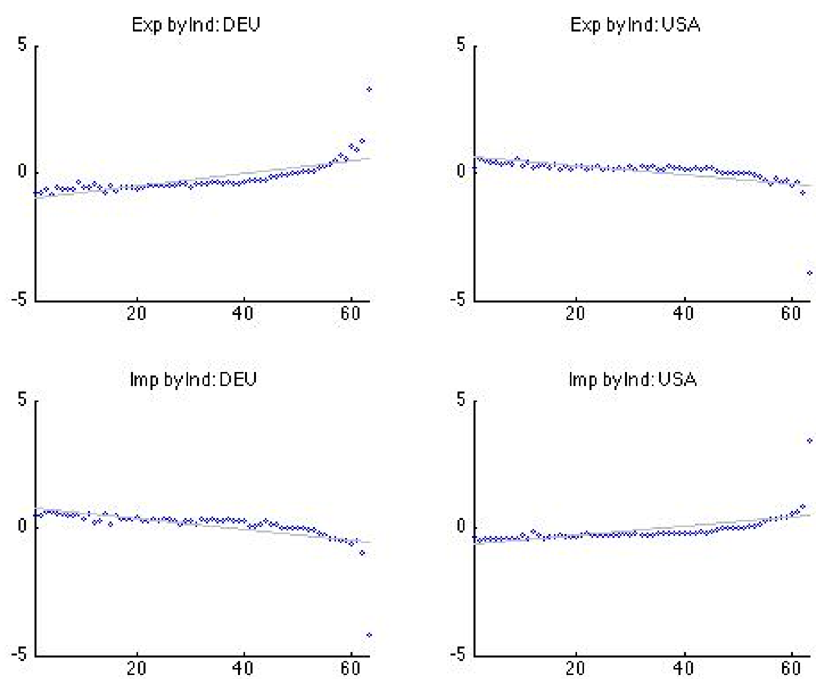
Note: the horizontal axis reports the 63 industries in order of increasing λ. The vertical axis reports the percentage change in trade.

Figure 2: Changes in trade flows across industries: $\gamma = 0.7$



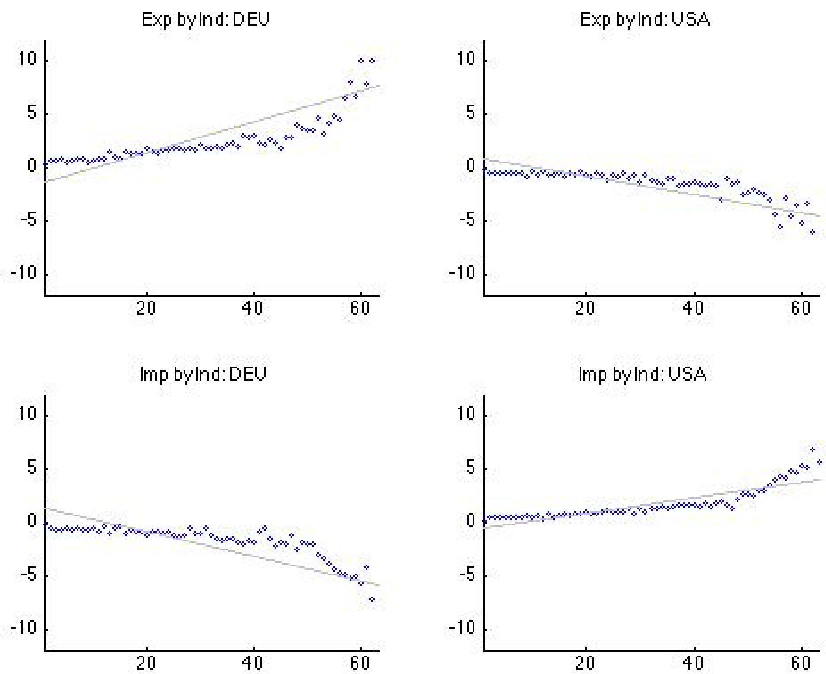
Note: the horizontal axis reports the 63 industries in order of increasing λ. The vertical axis reports the percentage change in trade.

Figure 3: Changes in trade flows for Germany and US: $\gamma = 0.3$



Note: the horizontal axis reports the 63 industries in order of increasing λ. The vertical axis reports the percentage change in trade.

Figure 4: Changes in trade flows for Germany and US: $\gamma = 0.7$



Note: the horizontal axis reports the 63 industries in order of increasing λ. The vertical axis reports the percentage change in trade.