Comment: Inferring Trade Costs from Trade Booms and Trade Busts

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Abstract

Jacks et al. (2011) offer an alternative to price gaps to quantify trade costs. Implementing a method which consists in deducing international trade costs from trade flows, they argue that the reduction in trade costs was the main driving force of trade growth during the first globalization (1870-1913), whereas economic expansion was the main driving force during the second globalization (1950-2000). We argue that this important result is driven by the use of an *ad hoc* aggregation method. What Jacks et al. (2011) capture is the difference in the relative starting trade of dyads experiencing faster trade growth in the first and second globalization. More generally, we cast doubts on the possibility to reach conclusions of such nature with a method that infers trade costs from trade flows, and then uses these costs to explain trade flows. We argue that it can only rephrase the information already contained in openness ratios.

Keywords: Trade costs, globalization, gravity model, aggregation, structure effect.
JEL Code: F14, N70

1 Introduction

Jacks and his coauthors offer in several papers a method for inferring international trade costs from trade flows.[1] Using the general equilibrium model of Anderson and van Wincoop (2003), they calculate trade costs (defined as all barriers to trade, notably transportation and transaction costs) and their evolution during the first and second waves of globalization (1870-1913 and 1950-2000) as well as the interwar period (1921-1939)

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[1]The method is developed in Jacks et al. (2008), Jacks et al. (2010), Novy (2013) and Jacks et al. (2011). We will use this latter paper as a reference

thanks to the impressive set of data they collected on trade flows, GDP and exports between 27 countries[2]. They provide a decomposition of the growth of trade caused by the reduction in trade costs and economic expansion. They use their computations to underline a difference of nature between the two globalizations:

> *"Our results assign an overarching role for our trade cost measure in the nineteenth century and the interwar trade bust. In contrast, when explaining the post-World War II trade boom, we identify a more muted role for the trade cost measure." (p. 196).*

This is potentially an important result that sheds light on the globalization processes. However, that result is actually driven by an *ad hoc* method of aggregation that captures structure effects. The inferred difference between the two globalization comes from the fact that the dyads with the fastest growing trade in the first wave of globalization start with very small trade. This is not the case in the second wave of globalization. Using a three-countries version of Anderson and van Wincoop (2003)'s model for the aggregation of bilateral trade costs shows that there was no difference in nature between the two globalizations. More generally, we cast doubt on the possibility to distinguish the effect of trade costs and economic expansion through an approach that relies only on the study of trade flows. Deducing trade costs from trade flows, and then using trade costs to explain trade flows is essentially a circular reasoning. Therefore, Jacks *et al.*'s approach cannot be an alternative to traditional investigations of impediments to trade, such as commodity price gaps.

This paper starts by presenting Jacks *et al.*'s approach of the measure of trade costs, and insists on its relevance at the bilateral level to control for multilateral trade barriers in gravity regressions (section 2). It then highlights that the result on a difference of nature between the two globalizations is paradoxical since it cannot be deduced from a comparison of the evolution of openness ratios. Section 3 shows that the conclusion is only driven by the authors' *ad hoc* aggregation method. We propose a microfounded way to aggregate trade costs and the puzzle fades away. Section 4 explores the reasons why Jacks *et al.*'s aggregation technique ends up providing different results for the two globalizations. We argue that what Jacks *et al.* misleadingly attribute to unequal trade costs decreases between the two globalizations is instead a difference in the distribution of trade growth over trading partners.

2 Deducing trade costs from trade flows, explaining trade flows with trade costs

Although it is consistent with many models of international trade, Jacks, Meissner and Novy's work is primarily based on the general equilibrium model framework of Anderson and van Wincoop (2003). n countries, each represented by a maximizing consumer, exchange goods over one single period. In this Armington world, production is not modelized[3] and each country is initially endowed with a differentiated representative good. Trade occurs because of consumers' taste for diversity. The preferences of all countries are assumed to be identical and modelized by a Constant Elasticity of Substitution (CES) utility function.

Anderson and van Wincoop (2003) use this model to microfound gravity equations and solve Mc Callum (1995)'s border puzzle by highlighting that bilateral trade does not depend on bilateral trade barriers *per se*, but bilateral trade barriers relative to impediments to trade with all other trading partners. Anderson and van Wincoop (2003) show that the equilibrium imposes the following relation:

$$x_{ij} = \frac{y_i y_j}{y^W} \left(\frac{t_{ij}}{P_i P_j} \right)^{1-\sigma} \tag{1}$$

where x_{ij} are real exports from i to j, y_i is real output of country i, y^W is the world real output, σ is the elasticity of substitution, P_i is the price index in country i and can be interpreted as multilateral trade barriers, and t_{ij} is the trade costs factor between i and j. Trade costs factors are assumed to be symmetric, i.e. $t_{ij} = t_{ji}$.

[2] Argentina, Australia, Austria, Belgium, Brazil, Canada, Denmark, France, Germany, Greece, India, Indonesia, Italy, Japan, Mexico, the Netherlands, New Zealand, Norway, the Philippines, Portugal, Spain, Sri Lanka, Sweden, Switzerland, the United Kingdom, the United States, and Uruguay. The data contain 130 country pairs.

[3] In the working paper version of Jacks et al. (2010), the authors provide a version of the model with production. The key equation is identical to the one of the model without production.

Jacks *et al.* first depart from Anderson and van Wincoop (2003) by eliminating the multilateral resistance variable (P_iP_j) from the gravity equation. As in Novy (2013), they use the Head-Ries index (Head and Ries (2001)) to express bilateral trade barriers not relatively to multilateral trade barriers modelized by the price index, but relatively to domestic trade costs. In this case, trade flows are no longer compared to outputs, but to internal trade x_{ii}[4]. The equation above becomes:

$$\left(\frac{x_{ii}x_{jj}}{x_{ij}x_{ji}}\right)^{\frac{1}{2(\sigma-1)}} = \left(\frac{t_{ij}t_{ji}}{t_{ii}t_{jj}}\right)^{\frac{1}{2}} = 1 + \tau_{ij} \tag{2}$$

The last equality defines τ_{ij}, the geometric mean of trade costs from country i to j and j to i *relative to intra-national trade costs in countries i and j* (no assumption of symmetry of bilateral trade costs is imposed). It is the trade cost measure used by the authors.

This simple step offers a significant breakthrough in the microfoundations of gravity equations. Comparing bilateral trade flows to intranational trade allows to integrate Anderson and van Wincoop (2003)'s caveat against omitted variable bias while getting rid of multilateral trade barriers. This is important when multilateral trade barriers cannot be estimated, e.g. when we only have data on trade for one country. Jacks et al. (2011) take advantage of this feature in the fifth section of their article in regressing their measure of trade costs between two countries on a set of proxies for trade costs, such as the distance between trade partners, tariffs, or the volatility of the exchange rate. This is a very useful approach.

However, Jacks, Meissner and Novy also suggest in their article that Anderson and van Wincoop (2003)'s model can be used to move away from the gravity regression approach. Instead of explaining trade flows by observable proxies for costs, they quantify the impact of all impediments to trade: *"We, therefore, infer trade costs from trade flows. This approach allows us to capture the combined magnitude of tariffs, transport costs, and all other macroeconomic frictions that impede international market integration but which are inherently difficult to observe. We emphasize that this approach of inferring trade costs from readily available trade data holds clear advantages for applied research: the constraints on enumerating — let alone, collecting data on — every individual trade cost element even over short periods of time makes a direct accounting approach impossible."* (p.131).

Our point is that a method that uses trade flows alone can teach us much about their determinants. When departing from Anderson and van Wincoop (2003)'s multilateral resistances, the arbitrage condition Jacks *et al.* base their computation on is an equality between a Marginal Rate of Substitution (MRS) and a price ratio for a CES utility function, or more precisely the product of two such equalities, one from the program of each trade partner. Appendix A derives equation (2) this way without passing through multilateral resistance. The inference of trade costs from trade flows is tantamount to using the relation between quantities and prices given by a demand curve derived from fully specified exogenous preferences.

This is of course no reason in itself to disregard the method. Yet it cannot be used to answer *"the central question of what drives trade booms and busts"*(p. 186) as the authors do in section 6 of their article, because the reasoning is circular: first calculate trade costs from trade flows, then explain trade flows from the inferred trade costs.

Formally, the authors take the logarithm of the key equation of their article (2) to decompose the product of bilateral trade flows between i and j in four terms:

$$ln(x_{ij}x_{ji}) = 2ln(y_i + y_j) + ln(s_is_j) + 2(1-\sigma)ln(1+\tau_{ij}) + \left(\frac{x_{ii}x_{jj}}{y_iy_j}\right) \tag{3}$$

Where $s_i = y_i/(y_i + y_j)$. By calculating the GDP-weighted average of the evolution of these terms over the first and second globalizations, the authors attribute the evolution of trade flows to four components: output growth, increasing income similarity, changes in trade costs and a fourth term that can be interpreted as a trade diversion effect.

[4]Due to data limitations, the authors use the relation $x_{ii} = GDP_i - EXPORTS_i$ to get internal trade. We follow them. Concerns about the fact that GDP is measured in added-value and exportations as gross value are addressed in appendix B of Jacks et al. (2011).

Since the trade costs measure is assimilated to trade flows relative to domestic activity, they simply restate an information already contained in any measure of trade flows relative to economic size, like an openness ratio defined for instance as the ratio of exportations to GDP. However the main conclusion in Jacks *et al.*'s article, namely that the first globalization was driven more by the decrease in trade costs than the second one, requires the absence of circularity. Indeed, when we decompose the level of exportations of a country as the product of its GDP and its openness ratio, we find results that are different from theirs (see table 1).[5] The increase in exportations is mainly explained by GDP growth for the large majority of the 27 countries in the data. On average, this decomposition attributes 74% (183/246) of the growth in trade to the increase in GDP in the second globalization and 60% in the first globalization. This is very much in contrast to Jacks *et al.*[6] :

> *"For the pre-World War I period, we find that declines in the trade cost measure explain roughly 60% of the growth in global trade. [...] Conversely, we find that only 31% of the present-day global trade boom can be explained by the decline in the trade cost measure. [...] The contribution of the two trade booms suggests that major technological breakthrough in the nineteenth century such as the steamship, the telegraph, and refrigeration may have been relatively more important than technological innovations in the second half of the twentieth century such as containerization and enhanced handling facilities." (p. 186).*

This contrast between both decompositions of the growth of exports is at the center of the argument by Jack *et al.* As the next section shows, it is actually driven by the *ad hoc* way they aggregate trade costs.

3 *Ad hoc* aggregation of trade costs

Jacks *et al.*'s conclusion on a difference of nature between the two globalizations is based on an aggregate trade costs measure that provides a summary statistic of the evolution of trade costs across all dyads in the sample, as well as for different regions of the world. To move from bilateral costs τ_{ij} to an aggregate measure of trade costs, the authors use an arithmetic mean over dyads, weighted by the sum of the GDP of the two trade partners.

There is no justification for this aggregation method. We argue that all the results they reach that are not a reformulation of the evolution of the openness ratio during the two globalizations come from this aggregation method.

Anderson and van Wincoop (2003)'s model can be used to calculate the aggregate trade costs a single country faces in its trade with all its trading partners. Indeed, using a two-countries model where all trade partners of country i are treated as one single country provides an aggregate measure of trade costs that does not rely on any *ad hoc* aggregation method but instead on microfoundations. Since all trade flows data are not available, it is also possible to use a three-countries model, with country i, its trading partners present in the data, and the rest of the world.

Let us note υ_i the corresponding trade cost faced by country i with all its trading partners in the data. Its expression is given by Jacks *et al.*'s key equation (2) applied to a three-countries model:

$$1 + \upsilon_i = \left(\frac{x_{ii} x_{pp}}{x_{ip} x_{pi}} \right)^{\frac{1}{2(\sigma - 1)}} \tag{4}$$

where x_{ip} and x_{pi} are respectively real exports and imports of i from and to its trade partners in the data, and x_{pp} is the volume of trade within and between the trading partners present in the data. This 'domestic trade' variable now includes cross-border trade.

Using this measure of trade costs, we provide the same decomposition in four terms of the increase in trade flows during the two globalizations as in the authors' article for the countries with the most trade

[5] We follow the authors in interpreting log differences as percentages. However, one should keep in mind that given the size of the changes, this is a very inexact approximation.

[6] Contributions of growth in income similarity and of change in multilateral factors are negative.

	First Globalization 1870-1913			Second Globalization 1950-2000		
	Exports	GDP	Openness Ratio	Exports	GDP	Openness Ratio
Argentina	292	251	40	116	132	-16
Austria	89	102	-13	379	185	194
Australia	174	152	22	114	191	-77
Belgium	195	86	109	251	150	101
Brazil	174	101	73	184	239	-55
Canada	233	170	64	258	192	66
Denmark	200	113	87	230	142	88
France	117	70	48	260	172	87
Germany	168	119	48	391	175	216
Greece	140	99	42	227	218	9
India	147	41	105	161	216	-54
Indonesia	220	87	133	263	232	31
Italy	151	83	69	335	188	147
Japan	337	104	233	448	281	167
Mexico	189	143	46	296	238	59
Netherlands	230	92	138	298	173	125
New Zealand	184	186	-2	307	133	174
Norway	.	.	.	70	181	-111
Philippines	218	92	126	237	213	24
Portugal	74	57	17	319	208	111
Spain	171	76	96	496	230	266
Sri Lanka	172	92	81	39	201	-161
Sweden	150	92	58	240	134	106
Switzerland	105	108	-3	250	132	118
UK	125	81	44	196	122	74
Uruguay	261	165	96	48	94	-46
USA	208	166	42	241	170	72
Average	**178**	**107**	**71**	**246**	**183**	**63**

Table 1: Decomposition of the growth of exportations between GDP growth and Openness ratio growth, log differences (interpreted as percentages). Figures for Norway are not given because the dissolution of the union between Norway and Sweden (1905) makes them meaningless.

1870-1913	Contribution of growth in output	Contribution of growth in income similarity	Contribution of change in trade cost measure	Contribution of change in multilateral factors	Average growth of bilateral trade flows
	JMN 2011, unweighted				
	195	3	251	-14	435
	JMN 2011, GDP-weighted				
	225	**-11**	**290**	**-18**	**486**
	JMN by country, unweighted				
France	154	24	168	-17	329
UK	168	18	122	-18	290
USA	312	-51	322	-15	568
Average	222	-7	263	-17	461
	JMN by country, GDP-weighted				
France	187	-1	151	-12	325
UK	194	3	102	-13	286
USA	286	-29	244	-11	490
Average	228	-9	295	-13	501
	3 countries model				
France	205	-30	84	-8	251
UK	204	-18	92	-9	269
USA	201	48	123	-8	364
Unweighted average	206	3	128	-12	325
GDP-weighted average	**203**	**8**	**163**	**-9**	**365**

Table 2: Decomposition of the growth in international trade (logarithms) with *ad hoc* averages and a microfounded aggregation method. First wave of globalization, 1870-1913. *JMN 2011* refers to the averaging over dyads, *JMN by country* by country refers to the averaging over trading partners for one country, *3 countries model* refers to the aggregation method we offer.

partners available in the data (France (24), the UK (25), the USA (23)). We also provide the unweighted and end-of-period-GDP-weighted averages for all countries in the sample. Results are displayed in tables 2 and 3 along with the results with the Jacks *et al.*'s method.[7]

Tables 2 and 3 highlight how much the decomposition between the decrease in trade costs and the income growth depends on the aggregation technique. When we use the microfounded aggregation method,[8] growth in output is the main driving force behind both waves of growth in international trade, contributing to about 56% (203/365) in the first wave and 66% (361/545) in the second one. It is no coincidence if these results are very similar to the ones in table 1: 60% (71/107) in the first globalization and 74% (183/246) in the second one. Insofar as a measure of trade costs is defined residually as everything that explains differences between domestic and international trade flows, it is bound to reword the information contained in an openness ratio.

[7]They include unweighted and end-of-period-GPD-weighted averages over country dyads of bilateral trade costs, such as provided in Jacks et al. (2011). We also display for France, the UK and the USA the trade cost measure averaged over trading partners faced by one country, as the results are presented (with a smaller data set) in Jacks et al. (2008, 2010). We also provide both averages of this measure over all countries in the data set.

[8]We selected the (GDP-weighted) average of our measure in order to allow a clear comparison with Jacks *et al.*'s results. There is of course no rational for such a summary statistic, but the results for France, the UK and the USA assure that the main conclusion of this exercice does not depend on averaging over countries.

1950-2000	Contribution of growth in output	Contribution of growth in income similarity	Contribution of change in trade cost measure	Contribution of change in multilateral factors	Average growth of bilateral trade flows
	JMN 2011, unweighted				
	353	8	148	-25	484
	JMN 2011, GDP-weighted				
	350	**3**	**137**	**-17**	**473**
	JMN by country, unweighted				
France	355	-1	201	-29	526
UK	280	29	54	-25	338
USA	343	11	112	-21	445
Average	349	9	124	-23	459
	JMN by country, GDP-weighted				
France	365	2	271	-21	617
UK	319	1	202	-20	502
USA	349	27	165	-16	525
Average	361	21	190	-19	553
	3 countries model				
France	371	-12	259	-16	602
UK	372	-59	122	-15	420
USA	372	-7	195	-12	548
Unweighted average	343	11	116	-18	452
GDP-weighted average	**361**	**15**	**183**	**-14**	**545**

Table 3: Decomposition of the growth in international trade (logarithms) with *ad hoc* averages and a microfounded aggregation method. Second wave of globalization, 1950-2000.

4 Sensitivity of the trade cost measure to structure effects

Our explanation of why Jacks *et al.*'s aggregate measure of trade costs yields different conclusion from table 1 is because it is sensitive to structure effects. To explain this idea, and for clarity purposes, let us consider a word where partners are symmetric (domestic trade is equal in i and j and x_ij=x_ji). From equation 2, we have:

$$1+\tau_{ij} = \left(\frac{x_{ii}}{x_{ji}}\right)^{\frac{1}{\sigma-1}} \tag{5}$$

This relation does not of course correspond to the arbitrage condition of country i, which would involve supply prices, but our aim here is to highlight the mechanism behind Jacks et al.'s aggregation. Note $\overline{a_j}$ the arithmetic mean of a_j over j ($\overline{a_j} = 1/n \sum_{j=1}^{n} a_j$). One can then compare the unweighted average of τ_{ij} according to equation (5) and the measure derived from the three-countries model in equation (4):

$$1+\tau_i = x_{ii}^{\frac{1}{\sigma-1}} \left(\overline{x_{ji}^{\frac{1}{1-\sigma}}}\right) \tag{6}$$

$$1+\upsilon_i = x_{ii}^{\frac{1}{\sigma-1}} (n \times \overline{x_{ji}})^{\frac{1}{1-\sigma}} \tag{7}$$

Except for the factor n (which is irrelevant since we are concerned with the evolution of the trade costs index) the two expressions (6) and (7) differ only by the mean they use. On the one hand, υ_i uses the arithmetic mean of imports x_{ji}. On the other hand, τ_i, because it uses an arithmetic mean over τ_{ij}, uses a mean power $1/(1-\sigma)$ of the imports, $\left(\overline{x_{ji}^{\frac{1}{1-\sigma}}}\right)^{1-\sigma}$. Appendix B establishes that the curvature properties of the function $x \to x^{\frac{1}{1-\sigma}}$, $\sigma > 1$ tend to draw the growth of τ_i towards the values of the growth of bilateral trade costs incurred with small trading partners.[9] On the contrary, υ_i puts more weight on big trade partners, consistent with intuition and their higher share of imports.

The authors partly correct this biais in the average of τ_{ij} by the use a end-of-period-GDP weighted average. However, as tables 2 and 3 show, weighting by the GDP of trade partners, besides not being theoretically justified, does not provide an accurate correction of the bias in the measure. One reason for this failure is that the relationship between GDP and the importance of trade flows is not systematic.

The average of the bilateral trade costs τ_{ij} captures both trade costs and the distribution of trade costs relative to the size of the trading partners. Through time, if dyads with small starting trade experience faster growth of trade than others, the decline of trade costs measured by τ_i will be overestimated compared to the decline of υ_i. This fits the data. For both globalizations, figure 1 plots the growth of trade flows (measured by $\Delta ln(\sqrt{x_{ij}x_{ji}})$) as a function of the initial value of trade (measured by the logarithm of the geometric average of bilateral average $ln(\sqrt{x_{ij}x_{ji}})$) for all dyads in the sample. This is also confirmed in the contrast between the rate of growth of exports (table 1) and the rate of growth of bilateral trade flows (table 2 and 3), as export growth was relatively faster than bilateral trade growth in the first globalization compared to the second ($486/178 > 473/246$). It confirms that the pairs of countries that initially traded little together experienced faster growth of trade compared to other pairs in the first than in the second globalization. This in an interesting result, but not the one presented by JMN.

5 Conclusion

Jacks, Meissner and Novy's method for inferring trade costs from trade flows simply reformulates the evolution of the openness ratio when it is used to calculate aggregate trade costs. This is because it only relates the two through an equality between MRS and price ratio. It appears more clearly when comparing the *ad*

[9]The 'size' of a country is used here to refer to the importance of the volume of its trade with i among trade partners of country i, regardless of its population and GDP.

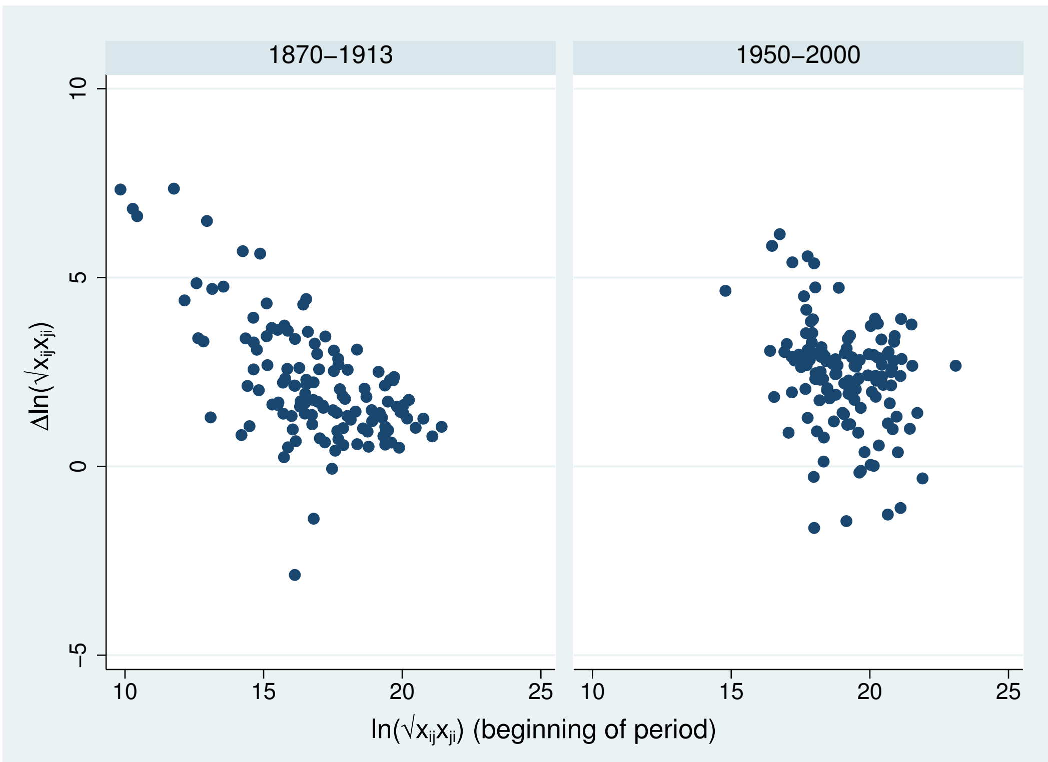

Figure 1: Growth of trade flows (logarithms) depending on their initial value for the first (1870-1913) and second (1950-2000) globalizations (logarithms).

hoc aggregation of bilateral trade costs to an aggregated measure of trade costs based on Anderson and van Wincoop (2003)'s model. Still, if their method fails to offer a full alternative to traditional investigations of trade costs, such as commodity price gaps, it provides an improvement in the microfoundation of gravity equations by substantially simplifying the way of correcting the omitted variable bias.

This characteristic of the proposed measure of trade costs is partly due to the all-inclusive definition of trade costs used by the authors. In such a model, costs are anything that causes consumptions from different countries' products not to be equal. To be sure, it is essential to highlight that trade costs cannot be reduced to tariffs or transportation costs, and to insist on the need for a quantification of all the impediments to international trade. But the concept of trade costs loses part of its interest if there are no causal alternatives to explain trade patterns. Such a definition is therefore bound to reword the information given by trade flows relative to output, such as contained in an openness ratio.

A Appendix: Deducing the measure of trade costs from an equality between a MRS and a price ratio

We derive in this appendix the key equation in Jacks et al. (2011). We do not start from Anderson and van Wincoop (2003)'s results as we want to highlight it is an equality between MRS and price ratio, or more precisely the product of two such equalities, one from the program of each trade partner.

Let us note C_{ki} the consumption by country i of good from region k, σ the elasticity of substitution, and β_k a positive distribution parameter, preferences of countries i and j's representative consumers are given by their respective utility functions:

$$U_i = \left(\sum_k \beta_k^{\frac{1-\sigma}{\sigma}} C_{ki}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$
$$U_j = \left(\sum_k \beta_k^{\frac{1-\sigma}{\sigma}} C_{kj}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

Trade costs imply that prices are specific to the country of consumption. We note p_k the supply price of the producer in country k net of trade costs, and p_{ki} the price of region k goods for region i consumers. We define $t_{ki} = p_{ki}/p_k$ the trade costs factor between k and i. Jacks *et al.*'s variable of trade costs between k and i, τ_{ki} is then defined as the trade costs factor between k and i relative to the domestic trade costs factor t_{ii}: $\tau_{ki} = t_{ki}/t_{ii} - 1$. In all that follows, we use the same notations τ_{ki} for the geometric average of τ_{ki} and τ_{ik}. Symmetry of bilateral trade costs does not need to be assumed.

Country i seeks to maximize U_i under the constraint $\sum_k p_{ki} C_{ki} = y_i$, where y_i is the output of country i. The first order conditions equate the Marginal Rates of Substitution (MRS) and the price ratio. In particular, for the goods produced by i and j:

$$MRS_{ji} = \frac{\frac{\partial U_i}{\partial C_{ji}}}{\frac{\partial U_i}{\partial C_{ii}}} = \left(\frac{\beta_j}{\beta_i}\right)^{\frac{1-\sigma}{\sigma}} \left(\frac{C_{ji}}{C_{ii}}\right)^{-\frac{1}{\sigma}} = \frac{p_{ji}}{p_{ii}}$$

Or equivalently with nominal values of trade flows, $x_{ji} = p_{ji} C_{ii}$ and $x_{ii} = p_{ii} C_{ii}$:

$$\left(\frac{\beta_j}{\beta_i}\right)^{\frac{1-\sigma}{\sigma}} \left(\frac{x_{ji}}{x_{ii}}\right)^{-\frac{1}{\sigma}} = \left(\frac{p_{ji}}{p_{ii}}\right)^{\frac{\sigma-1}{\sigma}}$$

We take the power σ of this equation. Country k's first-order optimality condition is given by a permutation of the indexes. We hence have the system of equations:

$$\left(\frac{\beta_j}{\beta_i}\right)^{1-\sigma}\left(\frac{x_{ii}}{x_{ji}}\right)=\left(\frac{p_{ji}}{p_{ii}}\right)^{\sigma-1}$$
$$\left(\frac{\beta_i}{\beta_j}\right)^{1-\sigma}\left(\frac{x_{jj}}{x_{ij}}\right)=\left(\frac{p_{ij}}{p_{jj}}\right)^{\sigma-1}$$

We can get rid of the β_j coefficients by taking the side-by-side product of those two equations:

$$\left(\frac{x_{ii}x_{jj}}{x_{ij}x_{ji}}\right)=\left(\frac{p_{ij}p_{ji}}{p_{ii}p_{jj}}\right)^{\sigma-1}$$

The main insight from this derivation is that when introducing the trade costs variable τ_{ij}, the exporter's supply prices disappear so that the trade cost factor can be expressed as a function of trade flows only. We get the equation on which Jacks, Meissner and Novy base their analysis:

$$x_{ij}x_{ji}=(x_{ii}x_{jj})(1+\tau_{ij})^{2(1-\sigma)}$$

B Appendix: Properties of means and structure effects

Let ϕ be a continuous bijective function. We can define m_ϕ the ϕ-mean of a sample $(a_j)_{1\leq j\leq n}$ as the image by ϕ^{-1} of the arithmetic mean of the image of the sample $(\phi(a_j))_{1\leq j\leq n}$. A common case is when ϕ is a power function $x\rightarrow x^\alpha$. It includes the arithmetic ($\alpha=1$), quadratic ($\alpha=2$) and harmonic ($\alpha=-1$) means. Formally:

$$m_\phi=\phi^{-1}\left(\frac{1}{n}\sum_{j=1}^{n}\phi(a_j)\right)$$

Properties of these means can be deduced from the monotonicity and convexity properties of the function ϕ. For instance, if ϕ is convex, the convexity inequality gives:

$$\phi(m_\phi)=\frac{1}{n}\sum_{j=1}^{n}\phi(a_j)\geq\phi\left(\frac{1}{n}\sum_{j=1}^{n}a_j\right)$$

If ϕ, and hence ϕ^{-1}, is also increasing, the ϕ-mean is superior to the arithmetic mean. Intuitively, the convexity of ϕ gives, relative to the arithmetic mean, more weight to the high values in the sample. Those results are reversed if ϕ is concave and increasing or convex and decreasing. Jacks, Meissner and Novy's aggregation method of the τ_{kj} is tantamount to using a ϕ-mean with ϕ the power functions $\phi: x\rightarrow x^{\frac{1}{1-\rho}}$, $\rho>1$ where the coherence with the model imposes an arithmetic mean. Hence, since ϕ is decreasing and convex, the substitution tends to overweight small countries.

This is a static result. We are interested in the dynamic behavior of trade flows. But Jacks *et al.*'s measure also overweights initially small trade partners in terms of the increase in trade flows. This can be seen by calculating the elasticities to the importations from country k (a_k) of the arithmetic mean (m) and of Jacks *et al.*'s mean (m_σ) (keeping importations from other trade partners a_j constant). The elasticity of a generic mean m_σ to a_k is given by $\varepsilon^k_{m_\phi}=\frac{1}{n}\frac{\phi'(a_k)}{\phi'(m_\phi)}\frac{a_k}{m_\phi}$, so that:

$$\varepsilon^k_m = \frac{1}{1+\sum\limits_{j\neq k}a_j/a_k}$$

$$\varepsilon^k_{m_\sigma} = \frac{1}{1+\sum_{j\neq k}(a_j/a_k)^{\frac{1}{1-\sigma}}}$$

The elasticity of the arithmetic mean m to a_k is increasing in a_k whereas the elasticity of m_σ is decreasing in a_k. A one-percent increase in the importations from k increases more the arithmetic mean of importations if k is initially an important importer, simply because k represents a larger part of trade. But it is the opposite with m_σ: the smaller the initial value of trade with k, the bigger the impact of its growth on m_σ. Therefore, Jacks *et al.*'s measure is biased toward the growth rates of costs incurred with small trade partners.

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