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Revealed Comparative Advantage: What Is It Good For?

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Abstract

This paper applies a widely-used class of quantitative trade models to evaluate the usefulness of measures of revealed comparative advantage (RCA) in academic and policy analyses. I find that, while commonly-used indexes are generally not consistent with theoretical notions of comparative advantage, certain indexes can be usefully employed for certain tasks. I explore several common uses of RCA indexes and show that different indexes are appropriate when attempting to (a) uncover countries' fundamental patterns of comparative advantage, (b) evaluate the differential effect of changes in trade barriers across producers of different products, or (c) identify countries who are relatively close competitors in a given market.

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1 Introduction

Since Balassa (1965), revealed comparative advantage (RCA) indexes have been employed in countless applications as a measure of the relative ability of a country to produce a good vis-à-vis its trading partners. The concept is simple but powerful: if, according to Ricardian trade theory, differences in relative productivity determine the pattern of trade, then the (observable) pattern of trade can be used to infer (unobservable) differences in relative productivity. However, in practice, developing the appropriate way to measure RCA has proven elusive.[1]

In this paper, I develop and apply insights from a widely-used class of quantitative trade models to answer the question, "What is the appropriate way to measure revealed comparative advantage?" and find that the answer is, "It depends." The model highlights two features that a theoretically-correct RCA index should possess. First, RCA measures based on bilateral trade flows are generally preferable to the most widely used indexes, which are based on trade flows that are aggregated across importers. This is because, in the presence of trade barriers, market conditions – such as the prices offered by competing producers – vary by destination. The former measures can separate bilateral and market-specific effects of trade distortions from those of comparative advantage, whereas the latter conflate these effects. Second, because comparative advantage is fundamentally a relative measure, an appropriate RCA measure must be a function of trade flows relative to an appropriate point of reference. Beyond this, it turns out that the functional form and point of reference of the appropriate RCA index depends on its purpose.

I consider several common uses of RCA indexes and show that, while the most commonly employed indexes are not generally useful, in many cases there *is* an appropriate measure of RCA that is straightforward to calculate and to interpret in light of the model. When one is concerned with uncovering countries' fundamental patterns of comparative advantage – defined in terms of the opportunity cost of production in autarky – then the appropriate RCA index is a function of bilateral trade flows relative to those for a reference product and exporter. Such a measure removes product-market effects and exporter-market effects (including bilateral trade barriers) from observed trade flows, leaving only an exporter-product-specific component, which the model relates to comparative advantage.

One RCA measure that falls into this category is the regression-based index (RBI) described by Costinot et al. (2012), which uses a log-linear specification with fixed effects that control for product-market and exporter-market effects. I also consider an alternative "gravity-based" index (GBI) that uses the adding-up constraints of the model to isolate these effects. The RBI is very simple to implement, while the GBI turns out to have a computational advantage when the number of countries and products being studied is relatively large, and it inherits the attractive robustness properties of Poisson PML estimators, which have become quite popular for gravity estimations.

[1] See Yeats (1985) for an early critique of Balassa's RCA index, and Vollrath (1991) and De Benedictis and Tamberi (2004) for surveys and discussions of the properties of various proposed measures. There have been many subsequent attempts to develop an index with desirable properties, such as Hoen and Oosterhaven (2006), Yu et al. (2009), and Bebek (2011).

Turning to a common application of RCA indexes, I show that a bilateral, additive RCA index (BAI) is appropriate when predicting or evaluating the differential effect of changes in trade barriers on a country's exports across product categories. This index reflects the model's prediction that a decrease in the cost of exporting from one country to another causes the importer to reallocate expenditure toward the exporter's comparative advantage products and away from both other exporters and other products. I also define an index that measures the effect of patterns of comparative advantage on the responsiveness of a country's sector-wide exports to changes in trade barriers. The appropriate index is the weighted covariance, across product categories, of the BAI values of the country whose exporters experience a change in trade barriers and the values of a bilateral version of Balassa's (1965) index for the exporter of interest. This index captures the notion that, if two countries have similar patterns of comparative advantage, the trade barriers faced by one of the countries will be relatively influential upon the exports of the other, since the countries will be relatively close competitors in foreign markets.

Interestingly, none of the indexes employed in evaluating the effects of changes in trade barriers is a valid measure of countries' fundamental patterns of comparative advantage. This demonstrates that different measures of comparative advantage are appropriate for different purposes. In this case, the effect of a change in trade barriers does not depend only on the fundamental patterns of comparative advantage of the country of interest. It also depends on the interaction among these patterns for all countries, together with trade barriers and other distortions, in a given market. Therefore, the appropriate index relates product-level bilateral trade flows to aggregated product-market and bilateral values in a way that appropriately captures this interaction. The result is that measures like the RBI and GBI, alone, are not sufficient for tasks such as predicting or evaluating the effects of a change in trade barriers, while measures such as the BAI are not useful for tasks such as measuring countries' fundamental patterns of comparative advantage. Instead, particular measures are appropriate for particular tasks.

In addition to defining appropriate RCA indexes for each of these common tasks, I also briefly discuss the usefulness of such indexes for two other purposes. First, while measures of countries' fundamental patterns of comparative advantage can be correlated with country- and product-specific variables in exercises designed to uncover the sources of comparative advantage, I argue that it is more straightforward and equally consistent with the theory to regress bilateral trade flows directly on variables thought to determine comparative advantage, as in, e.g., Romalis (2004) and Chor (2010). I also argue that RCA measures are not generally useful as a tool for comparing countries' productivity across time periods.

I consider two empirical examples which highlight properties of some of the RCA measures that I propose. First, I evaluate the consistency of the ranking of comparative advantage implied by the model across destinations. I find that approximately 70% of product pairs are consistently ranked for an average pair of exporters and destinations.[2] I also find that fitted values of product-level

[2] Note that this measure should be interpreted against a benchmark of 50%, the expected value if trade flows were independent random draws. This value corresponds to a value of Goodman and Kruskal's γ, a measure of pairwise rank correlation lying in $[-1, 1]$, of 0.4.

trade flows based on the GBI explain well over 90% of the variation in the data. These results indicate that, despite its simplicity and tractability, the model has significant, though far from perfect, predictive power in the data. This is moderately encouraging for the usefulness of RCA measures but serves as a reminder that one should carefully consider the appropriateness of the model's assumptions in any particular application. Second, I compute values of the RBI, GBI, and Balassa's classic index (BI) using trade flows in the motor vehicles industry. The results are roughly consistent across indexes and subjectively plausible. Where discrepancies arise between the RBI and GBI, they appear to be related to the undesirable properties of log-linear OLS estimators pointed out by Santos Silva and Tenreyro (2006), suggesting that the GBI should be preferred in most cases where the two measures deviate. Interestingly, the GBI and BI turn out to yield quite similar results. While certainly not a general result, this does suggest that, despite its ad-hoc nature, due to its simplicity, it is reasonable to employ the BI as a summary device for descriptive analysis, keeping in mind that one should always compare *relative* values of the index.

This paper is related to several strands of the literature. In its primary message that there are simple measures of RCA that are consistent with theory and useful for various applications, it is closely related to the recent literature that has found simple sufficient statistics that fully capture an outcome of interest in the workhorse class of quantitative trade models. Notably, Arkolakis et al. (2012) and Burstein and Cravino (2015) show that the gains from trade can be expressed as simple functions of observable variables. In this paper, I show that similarly simple expressions can be employed for various other purposes, where ad hoc RCA measures have traditionally been used.

Several papers have used insights from quantitative trade models with micro-level heterogeneity, along with disaggregated trade data, to uncover countries' underlying patterns of comparative advantage: for example, Anderson and Yotov (2010), Costinot et al. (2012), Caliendo and Parro (2014), and Levchenko and Zhang (2016). However, this paper is unique in its focus on developing simple, useful, and theoretically-founded RCA indexes that can be employed in the countless applications for which ad hoc measures are typically used. By contrast, the papers mentioned are primarily interested in quantifying the effects of comparative advantage, across broadly-defined industries, on trade flows and welfare.

This paper is also related to the literature concerned with developing RCA indexes that improve upon Balassa's (1965) measure in some way. Such papers include Yeats (1985), Vollrath (1991), and Laursen (1998), and there are many more. However, this paper is quite distinct in its approach to the subject in that it relies on a widely-used class of quantitative trade models to determine the appropriate form of RCA indexes, rather than appealing to particular numerical properties of certain indexes.[3] This paper also makes the additional contribution of outlining a framework within which to develop additional forms and appropriate uses of RCA indexes and to identify tasks for which they are not well suited. In addition, by relying on a formal model, it makes clear the key assumptions that are needed for the use an RCA index to be appropriate at all: trade barriers

[3]The notable exception is Costinot et al. (2012) who propose a theoretically-founded RCA measure. However, they do not explore the usefulness of this measure for tasks other than their computation of the welfare gains from inter-industry patterns of comparative advantage.

that can be separated into bilateral and product-by-market-specific components and an elasticity of product-level trade flows to exporters' production and trade costs that is constant across products. Both of these indicate that RCA measures can be most appropriately used to study patterns of comparative advantage within somewhat narrowly-defined sectors.

Finally, this paper builds upon the insight of Deardorff (2014) that, in the presence of trade barriers, trade patterns may not reflect patterns of comparative advantage alone. In particular, Deardorff shows, both in a simple example and in a more general model, how fundamental comparative advantage and trade costs, together, determine the pattern of trade. In this paper, I use a model, which has a similar structure to Deardorff's, to explicitly show how countries' patterns of comparative advantage can be inferred from data on bilateral trade flows in the presence of trade barriers, and I go on to show how various measures of RCA can be derived from the model and employed in common tasks.

In the following section, I present the main results in the context of an extension of the Ricardian model of Eaton and Kortum (2002). In Section 3, I discuss appropriate RCA indexes for measuring fundamental patterns of comparative advantage, the differential effects of trade barriers, and the responsiveness of aggregate trade flows to changes in trade barriers. Section 4 presents two empirical examples, and the final section concludes. The Appendix shows that main results hold in a broader class of models, extends the results to a setting with comparative advantage driven by factor endowments, and discusses practical concerns that arise in calculating RCA measures when data on domestic trade flows is unavailable.

2 Theoretical Framework

I will evaluate the properties and usefulness of measures of revealed comparative advantage through the lens of a commonly-used class of many-country, many-good quantitative trade models. This class includes many of the models delineated by Arkolakis et al. (2012), generalized to allow for any pattern of comparative advantage across a potentially large finite number of products. In particular, this includes generalizations of Armington models such as Anderson and van Wincoop (2003), the Ricardian model of Eaton and Kortum (2002), and models with imperfect competition and a fixed number of (potential) firms, such as Chaney (2008) (with monopolistic competition) and Bernard et al. (2003) (with Bertrand competition).

For concreteness, I will derive the key results in the context of a model based on the purely Ricardian, perfect competition model of Eaton and Kortum (2002). However, I show in Appendix B that these results extend to models featuring imperfect competition and firm selection. The important feature shared by all these models is that the set of available technologies does not depend on international trade flows or barriers to trade. For example, this includes a model of monopolistic competition with a fixed set of potential producers who may select into exporting, such as Chaney (2008), but it does not include models in which firms may develop *new* technologies in response to changes in trade barriers, as in Rivera-Batiz and Romer (1991), Melitz (2003), or

Arkolakis et al. (2013). Still, in a model of monopolistic competition and free entry, such as Melitz (2003) with Pareto distributed firm productivity, all of the results that follow hold locally – i.e., if we hold fixed the set of products and technologies at their baseline equilibrium levels.

This framework provides an ideal setting within which to study the usefulness of RCA measures for several reasons. First, by allowing for ex-ante productivity differences across products, the environment maintains a straightforward link to the classical theory of comparative advantage, which initially motivated the concept of RCA. Second, it allows for intra-product trade, which is a staple feature of disaggregated international trade data. Finally, it implies that product-level trade flows follow a gravity equation. Given the well-known empirical success of this functional relationship, this implies that the model's quantitative implications can be taken seriously.

2.1 Technology

The world economy consists of $n = 1, ..., N$ countries. Goods are classified according to a three-tiered hierarchy and thus are identified by the triple (j, k, ω). There are $j = 1, ..., J$ sectors, each of which is made up of a finite number of product categories, $k = 1, ..., K^j$.[4] Each product category is made up of a continuum of varieties, $\omega \in [0, 1]$.[5]

The marginal cost of producing a unit of variety (j, k, ω) in country i and delivering it to country n is given by

$$c_{ni}^{jk}(\omega) = \frac{c_i^j d_{ni}^{jk}}{Z_i^{jk}(\omega)}, \tag{1}$$

where c_i^j is the overall cost of a bundle of production inputs in i for goods in sector j, $d_{ni}^{jk} \geq 1$ is an "iceberg" trade cost, and $Z_i^{jk}(\omega)$ is the productivity with which inputs can be turned into units of variety (j, k, ω) in i.

Similar to Eaton and Kortum (2002), $Z_i^{jk}(\omega)$ is a random variable distributed according to

$$F_i^{jk}(z) = e^{-T_i^{jk} z^{-\theta^j}}.$$

In this specification, T_i^{jk} determines the overall level of productivity in i for producing all varieties of product (j, k). The degree of dispersion in productivity across varieties of (j, k) is governed by $\theta^j > 1$, with a greater value of θ^j implying a lower variance. Variance in productivity across varieties leads to idiosyncratic within-product comparative advantage, giving rise to intra-product trade, while relative values of T_i^{jk} determine countries' comparative advantage across products and inter-product trade flows.

There are a few important features of the production technology to note. First, there is a constant marginal cost of delivering a good from i to n. Second, for a given country, production of

[4]The precise definition of a "sector" may vary. Depending on the scope of the analysis, it could be a particular manufacturing industry, such as textiles, the entire manufacturing sector, or all tradeable goods. I use the terms "product" and "product category" interchangeably.

[5]The assumption of a continuum of varieties within each product category is made purely for analytical tractability. Were there a finite number of varieties, the results that follow would hold in expectation.

every good in sector j is assumed to use inputs in the same proportions, meaning that comparative advantage is driven by differences in factor-neutral productivity, determined by the values of Z_i^{jk}. These features greatly simplify the analysis that follows and are innocuous in regard to all partial equilibrium (holding factor prices fixed) results, as differences in product-specific input costs can be subsumed in Z_i^{jk} without loss of generality. However, general equilibrium comparative static results do rely on this specification, which implies a tight link among technology, autarky prices, and equilibrium trade flows.[6] In Appendix C, I show how the results of this section can be extended to a framework with inter-product comparative advantage arising from factor endowment differences.[7]

2.2 Trade Costs

To simplify the analysis that follows, I assume that trade costs can be separated into a sector-specific bilateral component and an importer-product-specific component:

$$d_{ni}^{jk} = d_{ni}^{j} d_{n}^{jk}, \quad \forall n \neq i, \tag{2}$$

and $d_{nn}^{jk} = 1$, for all n, j, and k. The first component captures trade costs specific to a pair of countries for a given sector, such as the effects of geographical distance and membership in a customs union.[8] The second component captures product-specific trade barriers in each destination market, such as customs requirements and import tariffs. Such a restriction is necessary to allow for any inference regarding comparative advantage to be made from data on trade flows. Otherwise, any pattern of trade flows could be rationalized by a particular set of trade costs, regardless of the underlying patterns of comparative advantage.

While this restriction is unlikely to hold exactly in the data, there are reasons to suggest that it is a reasonable approximation. For example, it is consistent with import tariffs that adhere to the Most Favored Nation principle of the World Trade Organization. It is also noteworthy that, for many of the purposes of RCA measures – for example, the measures of fundamental comparative advantage in Section 3.2 and the specification for an estimation of the differential effects of changes in trade barriers (12) – idiosyncratic deviations from (2) are not problematic.

The necessity of such an assumption suggests that the definition of a sector in applications of RCA measures must be sufficiently narrow that it is reasonable to assume that bilateral trade barriers do not vary significantly and systematically across products. For example, while the effect of distance on transportation costs is likely to be similar across products in the machinery and transport equipment industries, it is more likely to differ between agricultural products and

[6] I am thankful to a referee for pointing this out. It is also worth noting that, while factor endowment differences have been shown to be an important driver of inter-industry trade (see, e.g., Romalis, 2004), neutral technology differences have also been found to be quite important (see, e.g., Trefler, 1995), and it remains unclear how important factor endowments are in determining intra-industry trade flows.

[7] This extension draws on insights on the relationship between the factor content of trade and factor prices by Deardorff and Staiger (1988), Deardorff (2000), and Burstein and Vogel (2011). Also, see Razhev (2015) for a recent treatment of comparative advantage driven by micro-level input-output linkages.

[8] Because it may be the case that $d_{ni}^{j} \neq d_{in}^{j}$, this specification also allows for any form of asymmetry in trade costs, for example due to border costs that vary by country, as in Waugh (2010).

electronics. In Section 4, I return to this issue, using product-level trade data to evaluate the reasonableness of this restriction.

2.3 Market Structure and Demand

Markets are perfectly competitive, which implies that the price actually paid by buyers in n for variety (k,ω) is

$$p_n^{jk}(\omega) = \min_i\{c_{ni}^{jk}(\omega)\}.$$

A representative consumer in country n maximizes a nested Spence-Dixit-Stiglitz utility function over all varieties of all products, which implies that expenditure on product (j,k) is given by

$$X_n^{jk} = \tilde{\beta}_n^{jk}\left(\frac{P_n^{jk}}{P_n^j}\right)^{1-\sigma^j} X_n^j,$$

and expenditure on variety (j,k,ω) is given by

$$x_n^{jk}(\omega) = \left(\frac{p_n^{jk}(\omega)}{P_n^{jk}}\right)^{1-\eta^{jk}} X_n^{jk},$$

where $\eta^{jk} > 1$ is the elasticity of substitution across varieties of product k; $\sigma^j > 1$ is the elasticity of substitution across products; $\tilde{\beta}_n^{jk}$ is an exogenous demand shifter, which captures any factors other than relative prices that influence expenditure on product (j,k) in n; $P_n^{jk} = \left(\int_0^1 p_n^{jk}(\omega)^{1-\eta^{jk}} d\omega\right)^{\frac{1}{1-\eta^{jk}}}$; $P_n^j = \left(\sum_{k=1}^{K^j} \tilde{\beta}_n^{jk}(P_n^{jk})^{1-\sigma^j}\right)^{\frac{1}{1-\sigma^j}}$; and X_n^j is total expenditure by n on all products in sector j.

2.4 International Trade Flows

Because all variables and parameters are defined at the sectoral level, to avoid excessive notation, I suppress the sector superscript, j, throughout the remainder of the paper. However, the reader should keep in mind that all terms are implicitly allowed to vary across sectors.

Following the analysis of Eaton and Kortum (2002), it can be shown that the share of n's expenditure on product k that is devoted to varieties supplied by i is given by

$$\pi_{ni}^k \equiv \frac{X_{ni}^k}{X_n^k} = \frac{T_i^k(c_i d_{ni}^k)^{-\theta}}{\Phi_n^k}, \tag{3}$$

where $\Phi_n^k \equiv \sum_i T_i^k(c_i d_{ni}^k)^{-\theta} = \gamma^k(P_n^k)^{-\theta}$.[9] In addition, it is straightforward to show that the share of n's total expenditure on tradeable goods that is devoted to product k is given by

$$\frac{X_n^k}{X_n} = \beta_n^k\left(\frac{\Phi_n^k}{\Phi_n}\right)^{\frac{\sigma-1}{\theta}}, \tag{4}$$

[9] The constant $\gamma^k = \Gamma(1-(\eta^k-1)/\theta)^{\frac{\theta}{\eta^k-1}}$, where $\Gamma(\cdot)$ is the gamma function.

where $\Phi_n \equiv \left(\sum_k \beta_n^k (\Phi_n^k)^{\frac{\sigma-1}{\theta}}\right)^{\frac{\theta}{\sigma-1}} = P_n^{-\theta}$.[10] By combining (3) and (4) and summing across the set of products, total sector-level trade flows from i to n can be expressed as

$$\pi_{ni} \equiv \frac{X_{ni}}{X_n} = \frac{T_{ni}(c_i d_{ni})^{-\theta}}{\Phi_n}, \tag{5}$$

where $T_{ni} = \sum_k T_i^k \beta_n^k (d_n^k)^{-\theta} \left(\frac{\Phi_n^k}{\Phi_n}\right)^{\frac{\sigma-1}{\theta}-1}$.

Equations (3) and (5), which relate product-level and aggregate trade flows to countries' technologies and costs, form the basis of the analysis that follows. Equation (3) demonstrates that a country will import relatively more of product k from a source that is relatively efficient (a high value T_i^k) or has relatively low trade or production costs. Aggregate trade flows, given by equation (5), follow a very similar relationship, except that in the place of the technology parameter T_i^k is the bilateral term T_{ni}. This term summarizes the effect of both i's overall efficiency level and the strength of i's inter-product comparative advantage on its overall exports to n. It implies that i will export relatively more to n if it is relatively efficient at producing products for which n has greater demand (higher β_n^k), lower import costs, and (if $\theta > \sigma - 1$) relatively little access to efficiently produced varieties of k from other sources, which is summarized by the price parameter Φ_n^k.[11]

2.5 Comparative Advantage in the Model

Before examining the usefulness of various measures of revealed comparative advantage, it is helpful to explore the relationship between the traditional notion of comparative advantage and observed trade flows in the model. According to the standard definition, due to Haberler (1930), a country has a comparative advantage in producing a given product if, in autarky, it has a lower opportunity cost of producing it, versus another product, than another country.[12] In the model, this concept is consistent with the following definition:

Definition 1. *Country i has a comparative advantage in producing product k, compared to country i' and product k', if*

$$\frac{\bar{P}_i^k}{\bar{P}_i^{k'}} < \frac{\bar{P}_{i'}^k}{\bar{P}_{i'}^{k'}},$$

where $\bar{P}_i^k$ is the counterfactual price index for product k in i given that $d_{ni} \to \infty$, for all $n \neq i$.

The following result demonstrates that there is a straightforward mapping between technology

[10] The parameter $\beta_n^k = \tilde{\beta}_n^k (\gamma^k)^{(1-\sigma)/\theta}$. This normalization is purely for notational convenience, as it eliminates constants in equation (4) and the expression for Φ_n, and it plays no role in the analysis that follows.

[11] The condition that $\theta > \sigma - 1$ implies that the (effective) elasticity of substitution across sources of a given product is greater than the elasticity of substitution across products. If there were a continuum of products, this condition would be necessary for P_n to be well-defined. While not mathematically necessary with a finite number of products, if $\sigma - 1 > \theta$, then the counterintuitive result holds that the exports of a country of a given product to a given destination are increasing in the productivity of a competing source country for the same product. This restriction is generally found to hold in empirical studies (e.g., Broda and Weinstein, 2006).

[12] See Deardorff (2005) for a review of the development of the theoretical concept of comparative advantage over time.

parameters in the model and this conception of comparative advantage.

Lemma 1. *Country i has a comparative advantage in producing product k, compared to country i' and product k', if and only if*

$$\frac{T_i^k}{T_{i'}^k} > \frac{T_i^{k'}}{T_{i'}^{k'}},$$

where comparative advantage is defined according to Definition 1.

Proofs of this and all subsequent propositions are given in Appendix A. Lemma 1 demonstrates that, in this Ricardian environment, comparative advantage is determined entirely by relative values of the product-level technology parameters, T_i^k. Therefore, in what follows, I refer to rankings of products and countries according to relative values of T_i^k as countries' *fundamental* patterns of comparative advantage.

Given this result, equations (3) and (5) show how countries' patterns of comparative advantage, combined with the trade barriers they face, determine equilibrium trade flows. And, conversely, they tell us what can be inferred about comparative advantage from observed trade flows. The following two results highlight this relationship. The first makes clear how countries' patterns of comparative advantage determine the pattern of specialization when trade barriers are removed.

Proposition 1. *If $d_{ni}^k = 1$, for all n, i, and k, then for any two countries, i and i', and any two products, k and k', each country exports relatively more of the product for which it has a comparative advantage:*

$$\frac{E_i^k}{E_{i'}^k} > \frac{E_i^{k'}}{E_{i'}^{k'}} \iff \frac{T_i^k}{T_{i'}^k} > \frac{T_i^{k'}}{T_{i'}^{k'}},$$

where $E_i^k = \sum_{n \neq i} X_{ni}^k$.

This result formalizes the intuition that led to the revealed comparative advantage analysis of Balassa (1965) and countless subsequent studies. When trade is frictionless, countries export relatively more of their comparative advantage products. However, as Balassa and others have understood, this is not necessarily the case in a world with trade barriers and other distortions.[13] In the model, this is because, in the presence of bilateral trade costs, market conditions – summarized by d_n^k, Φ_n^k, and β_n^k – vary across destinations, and a country's total exports of a product depend on a convolution of these effects and the forces of comparative advantage.[14]

The next result, on the other hand, shows that, even in the presence of both non-trivial trade barriers and non-market demand distortions (i.e., differences in β_n^k across countries), relative *bilateral* trade flows reflect countries' fundamental patterns of comparative advantage.

Proposition 2. *For any set of technologies, $\{T_i^k\}$; input costs, $\{c_i\}$; trade costs, $\{d_{ni}\}$ and $\{d_n^k\}$; and demand shifters, $\{\beta_n^k\}$; and for any destination, n; any two source countries, i and i'; and any*

[13]This point is made particularly clearly by Deardorff (2014).

[14]Specifically, $E_i^k / E_{i'}^k = \sum_{n \neq i} \frac{T_i^k (c_i d_{ni}^k)^{-\theta}}{\Phi_n^k} \beta_n^k \left(\frac{\Phi_n^k}{\Phi_n}\right)^{\frac{\sigma-1}{\theta}} X_n \Big/ \sum_{n \neq i'} \frac{T_i'^k (c_i' d_{ni'}^k)^{-\theta}}{\Phi_n^k} \beta_n^k \left(\frac{\Phi_n^k}{\Phi_n}\right)^{\frac{\sigma-1}{\theta}} X_n$.

two products, k and k'; each source country exports relatively more to n of the product for which it has a comparative advantage:

$$\frac{X_{ni}^k}{X_{ni'}^k} > \frac{X_{ni}^{k'}}{X_{ni'}^{k'}} \iff \frac{T_i^k}{T_{i'}^k} > \frac{T_i^{k'}}{T_{i'}^{k'}}.$$

In the extension with multiple factors and factor endowment differences, presented in Appendix C, analogues of Propositions 1 and 2 hold for trade flows that have been adjusted by a measure that depends on the share of factor endowments that appear in the factor content of trade.

Note that these results rely on the assumption that θ is constant across products.[15] This is because θ governs the responsiveness of product-level trade flows to production and trade costs, as is clear from (3). If this degree of responsiveness differs across products, then the effects of these costs will also differ and cannot be separated from the effect of comparative advantage using relative trade flows. While there is some evidence that θ varies across broadly-defined industries (see, e.g., Caliendo and Parro, 2014), a constant value across products within such a grouping is likely a reasonable assumption. This reinforces the implication of the restriction on the form of trade costs (2) that analyses utilizing RCA indexes are most appropriately conducted over a range of products within similar industries.

3 Employing RCA Measures

Propositions 1 and 2 demonstrate that, in a widely used class of models, there is a tight link between the classic notion of comparative advantage and realized bilateral trade flows. This provides a formal theoretical underpinning of the concept of RCA and suggests that RCA measures may be useful in practice. It also provides some insight into the form that these measures should take, the assumptions necessary for them to be valid, and how they should be interpreted.

In particular, Propositions 1 and 2 suggest two principles that are useful in guiding the proper use of RCA measures in empirical analyses:

1. In the presence of bilateral trade costs and market-specific distortions, bilateral, rather than aggregated, trade flows should be used.

2. A valid measure of RCA is only defined relative to a valid point of reference.

The second principle simply reflects the fact that comparative advantage is, by nature, a relative concept, as has been clear since Ricardo. In the context of a country's fundamental patterns of comparative advantage, an RCA measure is only meaningful relative to a reference product and country.

Beyond these basic principles, it will become clear that there is no one-size-fits-all RCA measure but that particular measures, with particular functional forms and reference points, are suited to particular tasks. In fact, many of the measures introduced below are not theoretically correct measures of countries' fundamental patterns of comparative advantage but are nevertheless useful

[15] By contrast, variance in the elasticity of substitution, η^k, across products is not problematic.

and intuitive measures of a broader concept of comparative advantage, suited to a particular task. The remainder of the paper is focused on these practical concerns. In this section, I discuss how the lessons of Propositions 1 and 2 apply to Balassa's classic RCA index and then propose several new measures and discuss their application to several particular tasks: inferring countries' fundamental patterns of comparative advantage, predicting or evaluating the effects of changes in trade barriers, uncovering sources of comparative advantage, and comparing countries' relative productivity over time.

3.1 Balassa (1965) Revisited

By far the most widely used measure of RCA is Balassa's (1965) RCA index:

$$\text{BI}_i^k \equiv \frac{E_i^k/E^k}{E_i/E},$$

where $E_i = \sum_k E_i^k$, $E^k = \sum_i E_i^k$, and $E = \sum_{i,k} E_i^k$. Since its development, this index has been utilized in countless studies for many purposes and has the benefit of being simple and intuitive. Proposition 1 makes clear that, in a world with frictionless trade, the BI would be a theoretically-consistent indicator of comparative advantage, as relative values of BI have the same implications as relative values of E_i^k. However, this is not generally the case when trade barriers are present.

The Bilateral Balassa Index As a result, drawing on the insights of Proposition 2, I define the Bilateral Balassa Index, which is the bilateral analogue of the classic BI:

$$\text{BBI}_{ni}^k \equiv \frac{X_{ni}^k/X_n^k}{X_{ni}/X_n} = \frac{T_i^k (d_n^k)^{-\theta}/\Phi_n^k}{T_{ni}/\Phi_n}.$$

This index maintains the basic form and intuitive appeal of the BI, but it continues to be meaningful in a world with bilateral trade costs and market-specific distortions. It also adheres to the two principles listed above.

As with the BI, however, rather than being based on trade flows relative to a particular reference product and county, it is based on trade flows relative to a "bundle" of all exporters and a similar bundle of all products in the sector of interest. As a result, the BBI can be interpreted as a measure of country i's ability to deliver product k to market n, relative to a "typical" country and a "typical" product. This interpretation gives the BBI a degree of intuitive appeal. However, neither the BI nor the BBI is a particularly useful indicator of a country's fundamental patterns of comparative advantage. Specifically, whereas Proposition 2 shows that a value of $(X_{ni}^k/X_{ni'}^k)/(X_{ni}^{k'}/X_{ni'}^{k'}) > 1$ indicates that i has a comparative advantage in product k vis-à-vis country i' and product k', a value of $\text{BBI}_{ni}^k > 1$ has no such precise meaning.[16]

This is not to say that the BBI is not useful. Its intuitive appeal and straightforward mapping

[16] Of course, BBI_{ni}^k can substituted for X_{ni}^k in this expression without issue, as all components of the BBI other than X_{ni}^k cancel out.

into model variables makes it a useful starting point for descriptive analyses. Its relation to the model also makes clear that such a measure must be a bilateral one in order to be interpreted clearly, given that the implied meaning of a typical country and product is necessarily market-specific in the presence of bilateral trade barriers. Thus, I consider the BBI to be a more theoretically relevant alternative to the BI, maintaining its intuitive appeal while being much easier to interpret in light of the theory. I also show in Section 3.3 that the BBI is useful for another purpose.

3.2 Measuring Fundamental Patterns of Comparative Advantage

Though traditional RCA measures such as the BI are got generally useful as indicators of countries' fundamental patterns of comparative advantage, the literature does provide two promising, though slightly more involved, measures that accomplish this task. Both are based on equation (3). The first takes advantage of the log-linear form of (3), while the second uses the model's equilibrium conditions.

The Regression-Based Index Costinot et al. (2012), henceforth CDK, show that, in a model similar to the one of this paper, disaggregated trade flows can be decomposed into the following components:

$$\ln X_{ni}^k = \delta_{ni} + \delta_n^k + \delta_i^k + \varepsilon_{ni}^k, \tag{6}$$

where ε_{ni}^k is a mean zero disturbance. As is clear from (3), δ_i^k is determined by the value of $T_i^k c_i^{-\theta}$. Thus, the value of an exporter-product-specific fixed effect from a regression of the form of (6), denoted $\hat{\delta}_i^k$, is a theoretically consistent estimate of the relative productivity of i for product k (up to country- and product-specific scale factors). Because this measure is only defined relative to a reference country and product, I define the regression-based RCA index as follows:[17]

$$\text{RBI}_i^k \equiv e^{\hat{\delta}_i^k} = \frac{T_i^k / T_i^{k_0}}{T_{i_0}^k / T_{i_0}^{k_0}}.$$

The Gravity-Based Index Another measure of countries' fundamental patterns of comparative advantage can be obtained by decomposing disaggregated trade flows multiplicatively as follows:

$$X_{ni}^k = \phi_{ni} \phi_n^k \phi_i^k + \varepsilon_{ni}^k, \tag{7}$$

where ε_{ni}^k again represents a mean zero disturbance. It is clear that $\ln(\phi_i^k)$ has the same interpretation as δ_i^k in (6). Thus, any consistent estimate of ϕ_i^k also constitutes theoretically valid measure of fundamental comparative advantage.

There are many possible non-linear estimators based on (7). A particularly straightforward one is the method of moments estimator that sets the sample analogue of $E[X_{ni}^k - \phi_{ni}\phi_n^k\phi_i^k]$ equal to zero. French (2016b) shows that this estimator is equivalent to imposing the model's adding-up

[17] In the context of a linear regression, this is due to the technical requirement that dummy variables for one product and country must be omitted to avoid multicollinearity.

constraints – $X_{ni} = \sum_k X_{ni}^k$, $E_i^k = \sum_{n \neq i} X_{ni}^k$, and $M_n^k = \sum_{i \neq n} X_{ni}^k$ – and constraining the values of M_n^k, E_i^k, and X_{ni} predicted by the model to equal their values in the data. Then, the components of (7) can be computed as the solution to the following system of equations:

$$\hat{\phi}_i^k = \frac{E_i^k}{\sum_{n \neq i} \hat{\phi}_{ni} \hat{\phi}_n^k}, \qquad \hat{\phi}_n^k = \frac{M_n^k}{\sum_{i \neq n} \hat{\phi}_{ni} \hat{\phi}_i^k}, \qquad \hat{\phi}_{ni} = \frac{X_{ni}}{\sum_k \hat{\phi}_i^k \hat{\phi}_n^k}, \tag{8}$$

This estimator is also equivalent to a Poisson pseudo-maximum likelihood (PML) estimator that relates disaggregated trade flows to a set of importer-product, exporter-product, and importer-exporter fixed effects.[18] Because these adding-up constraints are the same ones imposed by structural gravity models, such as that of Anderson and van Wincoop (2003), I refer to this measure of RCA as the "gravity-based" RCA index (GBI). Similar to the CDK regression, $\hat{\phi}_i^k$ is only uniquely identified relative to a reference country and product, so I define the GBI as follows:

$$\text{GBI}_i^k \equiv \hat{\phi}_i^k = \frac{T_i^k / T_i^{k_0}}{T_{i_0}^k / T_{i_0}^{k_0}}.$$

The RBI and GBI have much in common. Both are theoretically-founded, making interpretation straightforward, and both are a measure of countries' fundamental comparative advantage. Because both are estimated using standard econometric techniques, both allow for straightforward hypothesis testing, such as testing whether particular relative productivity levels are statistically different across products or countries.[19] Both are also robust measures in that they only require that equation (3) hold in expectation, which implies that idiosyncratic deviations from the assumption of equation (2) are not problematic.

The key difference between the two is merely whether the moment condition used to estimate the exporter-product effect depends on trade flows in logs or in levels.[20] Whether one is favored over the is ultimately up to the researcher's discretion. However, there are a few practical differences that are worth consideration. In practice, the RBI works particularly well when the number of countries and products is relatively small and all values of X_{ni}^k are positive, and it is very convenient to estimate using any standard statistical software.[21] However, as the number of countries and products become large, performing the regression in (6) quickly becomes a computational challenge. Standard techniques require estimating coefficients on bilateral and country-product dummy

[18] As Fally (2015) shows, the Poisson PML estimator with fixed effects imposes the same adding-up constraints as the GBI. This equivalence also implies that (8) has a unique solution, if one exists, as Gourieroux et al. (1984) show is the case for Poisson PML.

[19] Note that the coefficient estimates depend on the choice of numeraire product and country, and the error term likely suffers from heteroskedasticity and is possibly correlated across observations. The statistics used to test such hypotheses should be robust to these issues.

[20] The distinction between these indexes is analogous to that between linear-in-logs OLS and PML, which has received a great deal of attention in the gravity estimation literature. See Head and Mayer (2014) for a thorough review.

[21] For example, CDK employs data on 21 countries and 13 industries.

variables, which can exhaust the memory capacity of most computers for large datasets.[22] These memory requirements can be avoided by using the iterative technique of Guimarães and Portugal (2010).[23] However, this technique is computationally intensive, particularly in the presence of zero-valued trade flows.[24] The GBI, by contrast, involves solving a system of non-linear equations, so it cannot be estimated simply using basic statistical software. However, computing the GBI is comparatively computationally efficient for large datasets with zero-valued trade flows.[25] Thus, the RBI is very convenient for small and medium-sized datasets – i.e., dozens of countries and product categories – while the GBI becomes more useful as datasets become very large – i.e., hundreds of countries and potentially thousands of product categories.

There are two econometric issues that can arise from the logarithmic form of (6), which underlies the RBI, depending on the properties of the error term. First, the estimation drops zero-valued observations. Because zeros in the data are unlikely to occur purely randomly, this introduces sample-selection bias into estimates of δ_i^k. For example, if a common, unobserved factor has a negative effect on trade flows and makes observing a zero more likely, then δ_i^k will be biased upward for exporter-product pairs with a relatively large number of zeros because OLS implicitly treats the dropped trade flows as "average" observations. Second, Santos Silva and Tenreyro (2006) show that RBI_i^k will be a biased estimator of T_i^k unless heteroskedasticity in ε_{ni}^k takes a particular form, due to Jensen's inequality and the log transformation. However, $\hat{\delta}_i^k$ will still be a consistent predictor of $\ln X_{ni}^k$, so this potential bias does not affect the RBI's validity as an index of fundamental comparative advantage.[26] Because the GBI does not depend on a transformation of X_{ni}^k, it does not suffer from either of these issues and is a consistent estimator of T_i^k as long as (3) is correctly specified. To summarize, if sample selection or computational efficiency is a concern for a large dataset with many zero-valued trade flows, the GBI offers some practical advantages which may come at the cost of requiring some application-specific coding. If neither is a major concern, the choice of RBI or GBI is primarily a matter of preference over whether to express the moment condition based on (3) in logs or in levels.

[22]For example, French (2016a) uses data on 132 countries and 4,608 product categories. Estimating (6) with this sample involves creating $N(N-1)+2K(N-1) = 1{,}224{,}588$ dummy variables. This estimation also involves millions of observations, even when excluding zero-valued trade flows, meaning that merely forming the matrix of regressors requires more than 30 terabytes of memory.

[23]This technique is implemented in the user-written Stata command **reg2hdfe**.

[24]French (2016b) notes that computation is slowed significantly when the sample is unbalanced, as is the case when zeros are dropped due to the log transformation of X_{ni}^k. When the number of observations across importer-product, exporter-product, and country pair groups is constant, the normal equations implied by (6) can be solved exactly as a function of group means, as with the within estimator with one-way fixed effects.

[25]Both the Guimarães and Portugal (2010) algorithm and iterating on (8) require simple calculations mostly involving group means/sums. However, because (8) allows the inclusion of zero-valued trade flows, the sample will always be balanced.

[26]For example, ignoring the sample-selection issue, the RBI is valid for testing whether $\ln T_i^k - \ln T_{i'}^k > \ln T_i^{k'} - \ln T_{i'}^{k'}$.

3.3 The Effects of Changes in Trade Barriers

While there are many studies in which it is useful to uncover countries' fundamental comparative advantage,[27] researchers utilizing RCA indexes are most commonly interested in the policy and welfare implications of countries' patterns of comparative advantage. Likely the most common use of RCA measures is in predicting or evaluating the effects of changes in trade barriers, especially tariffs, on a country's producers and exports. In fact, this was the impetus for the analysis of Balassa (1965), which gave rise to the widespread use of RCA indexes. Greenaway et al. (2008), Goldberg et al. (2010), Menezes-Filho and Muendler (2011), McCaig and Pavcnik (2012), and Autor et al. (2013) are recent examples of analyses of the differential effects of changes in trade barriers across products according to countries' patterns of comparative advantage. Even analyses that are mostly descriptive in nature – for example, Fertö and Hubbard (2003) and Tongzon (2005) – are often intended ultimately to elucidate the effects of past or prospective trade policies, such as tariffs and export subsidies.

As a result, I explore the usefulness of RCA measures for such tasks, first in measuring the differential effects of changes in trade barriers across products, and then in measuring the aggregate effects of changes in trade barriers. I demonstrate that the use of an RCA index in such contexts is consistent with the theory but that specific measures, which do not necessarily indicate countries' fundamental patterns of comparative advantage, are required.

3.3.1 Product-Level Effects of Changes Trade Barriers

A particular RCA index proves to be quite useful in measuring the differential effects of changes in trade barriers across products. To understand its form and function, consider the elasticity of trade flows of product k from i to n with respect to the bilateral trade cost associated with exporting from a third country, l, to n:[28]

$$\begin{aligned}\frac{\partial \ln(X_{ni}^k)}{\partial \ln(d_{nl})} &= \frac{\partial \ln(\pi_{ni}^k)}{\partial \ln(d_{nl})} + \frac{\partial \ln(X_{n}^k)}{\partial \ln(d_{nl})} \\ &= \theta \pi_{nl}^k - (\sigma - 1)(\pi_{nl}^k - \pi_{nl})\end{aligned} \tag{9}$$

The first collection of terms represents the direct effect of the increase in the prices of l's varieties of k on i's market share in n for k. The second represents the change in the allocation of n's expenditure across products in response to the changes in relative prices, where the relative price increase is greater – causing relative expenditure to fall – for the products in which l has a relatively large market share.

[27] Examples include investigating countries' patterns of relative productivity for evidence of particular patterns of specialization, technological change, or technology diffusion, such as Hidalgo et al. (2007), Kali et al. (2013), and Barattieri (2014).

[28] This partial elasticity is calculated holding constant production costs everywhere and total spending on tradeable goods in n.

The Bilateral Additive Index This expression motivates the definition of the Bilateral Additive Index:

$$\mathrm{BAI}_{ni}^{k} \equiv \frac{X_{ni}^{k}}{X_{n}^{k}} - \frac{X_{ni}}{X_{n}} = \frac{T_{i}^{k}(c_i d_{ni}^{k})^{-\theta}}{\Phi_{n}^{k}} - \frac{T_{ni}(c_i d_{ni})^{-\theta}}{\Phi_{n}}.$$

Using this definition, (9) can be rewritten as

$$\frac{\partial \ln(X_{ni}^{k})}{\partial \ln(d_{nl})} = \theta\pi_{nl} + [\theta - (\sigma - 1)]\,\mathrm{BAI}_{nl}^{k}, \tag{10}$$

where $\theta\pi_{nl}$ represents the hypothetical effect of d_{nl} on X_{ni}^{k} if l were to have no comparative advantage in any product – i.e., if $\pi_{nl}^{k} = \pi_{nl}$, for all k. The remainder of the expression represents the component of the effect of d_{nl} on X_{ni}^{k} that depends on l's level of comparative advantage for product k.

Thus, the BAI is useful if one is interested in the differential effects of a change in trade barriers across producers of different products. For example, if $\theta > \sigma - 1$, then the model has the following implications:

1. A decrease in d_{nl} is relatively more harmful for exporters to n, from any country other than l, who produce products for which BAI_{nl}^{k} is relatively large.

2. A decrease in d_{ni} is relatively more beneficial for exporters from i to n who produce the products for which BAI_{ni}^{k} is relatively small.

3. Domestic producers of goods for which BAI_{nn}^{k} is relatively large fare relatively well when tariffs on imports to n fall.

The first implication follows immediately from (10). The second follows from the analogue of (10) for the case in which $i = l$: $\partial \ln(X_{ni}^{k})/\partial \ln(d_{ni}) = -\theta(1-\pi_{ni}) + [\theta-(\sigma-1)]\mathrm{BAI}_{ni}^{k}$. For the third, define d_n such that $d_{ni} = d_n \tilde{d}_{ni}$ for all $i \neq n$. Then, $\partial \ln(X_{nn}^{k})/\partial \ln(d_n) = \theta(1-\pi_{nn}) - [\theta - (\sigma-1)]\mathrm{BAI}_{nn}^{k}$.

Example: Tariff Liberalization and Domestic Sales As an example of how the BAI is useful in formal analyses of the affects of trade barriers, consider the effect of a trade liberalization on a country's domestic sales. To keep the analysis simple, I hold constant all trade costs except for d_{n}^{k}, for a given n and all k, and assume that country n is a small open economy, meaning that foreign expenditure and production costs are unaffected by changes in d_{n}^{k}. Totally differentiating (3) shows that changes in X_{nn}^{k} are given by

$$d\ln X_{nn}^{k} = C_n + (\theta - (\sigma - 1))\left[m_{n}^{k}(d\ln d_{n}^{k} - d\ln \bar{d}_n) - \mathrm{BAI}_{nn}^{k}(d\ln \bar{d}_n - d\ln c_n)\right], \tag{11}$$

where C_n is a collection of country-specific terms, m_{n}^{k} is the import penetration ratio for product k in n, and $d\ln \bar{d}_n$ is the import-weighted average change in d_{n}^{k} across all products.[29] The first term

[29]Specifically, $C_n = d\ln(X_n) + \theta(M_n/X_n)(d\ln \bar{d}_n - d\ln c_n)$, $m_{n}^{k} = M_{n}^{k}/X_{n}^{k}$, and $d\ln \bar{d}_n = \sum_k (M_{n}^{k}/M_n) d\ln d_{n}^{k}$, where $M_{n}^{k} = \sum_{i\neq n} X_{ni}^{k}$ and $M_n = \sum_k M_{n}^{k}$.

contains all effects of the trade liberalization on domestic sales that are common across products. The first collection of terms in brackets represents the differential effect on sales of product k due to the relative magnitude of the product-level tariff change, and the second represents the effect due to domestic producers' comparative advantage in product k, measured by BAI_{nn}^k.

This suggests that a regression estimating the effect of a tariff liberalization on a country's domestic sales should take the following form:

$$\Delta \ln(X_{nn}^k) = \beta_0 + \beta_1(m_n^k \times \hat{\tau}_n^k) + \beta_2 \text{BAI}_{nn}^k + \varepsilon_n^k, \tag{12}$$

where $\hat{\tau}_n^k$ is the change in the import tariff for product k relative to the import-weighted average change in tariffs across all products.[30] Comparing this equation with (11), β_1 measures the direct effect of differential tariff changes on product-level domestic sales, and β_2 measures the indirect effect of the tariff liberalization, which depends on n's patterns of comparative advantage.

These results are in line with the intuition underlying the use of RCA indexes in predicting and evaluating the effects of trade policy on certain industries or producers, and they make clear that the BAI is the appropriate measure of RCA for such purposes. For example, a common practice when one is interested in the effect of a country's tariff liberalization on domestic production or employment is to include a measure of RCA in a regression of changes in the variable of interest on changes in tariffs.[31] This is an appropriate practice if the BAI is the measure employed and the regression takes the form of (12). However, it is noteworthy that the BAI is not interacted with product-level tariff changes in (12). This is because the domestic country's patterns of comparative advantage determine the effect of changes in production and *average* import costs on relative prices, not the direct effect of product-level tariff changes, which depends on the import penetration ratio.

This was a simple example, but the lessons are adaptable to many settings. For example, the basic form of (12) is preserved if one is interested in total domestic production, including domestic sales and exports, though an extra term must be included to capture the effect of changes in domestic production costs on exports.[32] Also, if one is interested in the effects of a reduction in tariffs in one country on the exports of another country, then, based on results 1 and 2, above, the appropriate measure is BAI_{nl}^k, where l is the exporting country facing the tariff change.

3.3.2 Aggregate Effects of Changes in Trade Barriers

A related question is the role of comparative advantage in determining the degree to which one country's aggregate trade flows are affected by changes in the trade costs faced by another country – in other words, how closely a pair countries compete to export to a given market. Consider the

[30] Specifically, $\hat{\tau}_n^k = \Delta \ln(1+\tau_n^k) - \sum_k (M_n^k/M_n)\Delta \ln(1+\tau_n^k)$. Note that a change in tariffs is not identical to a change in real iceberg trade costs because tariffs generate government revenue. If we assume that tariff revenue is rebated to households lump sum, then this only affects the values of C_n and c_n. Thus, this distinction has some effect on the interpretation of β_2 but not on the form of the regression equation.

[31] See, e.g., Goldberg et al. (2010) and Menezes-Filho and Muendler (2011)

[32] For a tariff liberalization in i, the analogue to (12) for domestic production is $\Delta \ln(Y_i^k) = \beta_0 + \beta_1(m_i^k \times \hat{\tau}_i^k) + \beta_2 \text{BAI}_{ii}^k + \beta_3 \sum_{n \neq i} \text{BAI}_{ni}^k \frac{X_{ni}^k}{X_{ii}^k} + \varepsilon_n^k$.

partial elasticity of total trade flows from i to n with respect to d_{nl}, for $l \neq i$:

$$\frac{\partial \ln(X_{ni})}{\partial \ln(d_{nl})} = \theta \pi_{nl} + [\theta - (\sigma - 1)] \sum_{k=1}^{K} \frac{X_{ni}^k}{X_{ni}} (\pi_{nl}^k - \pi_{nl}).$$

The first term represents the hypothetical response of X_{ni} to a change in d_{nl} if l were to have no comparative advantage in any product – i.e., if $\pi_{nl}^k = \pi_{nl}$, for all k. The second represents the additional effect due to the interaction of i and l's patterns of comparative advantage in n.

The Trade Elasticity Index Based on this expression, I define the Trade Elasticity Index:

$$\text{TEI}_{nil} \equiv \sum_{k=1}^{K} \frac{X_{ni}^k}{X_{ni}} \left(\frac{X_{nl}^k}{X_n^k} - \frac{X_{nl}}{X_n} \right).$$

It turns out that the TEI can be expressed as a weighted average of the interaction between the BBI and the BAI:

$$\text{TEI}_{nil} = \sum_{k=1}^{k} \frac{X_n^k}{X_n} \left(\text{BBI}_{ni}^k \times \text{BAI}_{nl}^k \right).$$

In fact, because the weighted average of BAI_{nl}^k is zero, TEI_{nil} is equivalent to the weighted covariance of the values of BBI_{ni}^k and BAI_{nl}^k. While this result may seem surprising, the intuition behind it is straightforward. The BBI measures country i's ability to deliver product k to n, relative both to other countries' ability to supply k to n – summarized by Φ_n^k – and to its own overall relative ability to supply all goods to n – measured by T_{ni}/Φ_n. The BAI measures the effect of country l's comparative advantage in product k in shaping the response to a change in d_{nl} of other countries' exports of k to n. Thus, if country i's pattern of comparative advantage, measured by the BBI, is strongly correlated with country l's pattern of comparative advantage, measured by the BAI, then i's exports to n will be relatively responsive – given l's overall market share in n – to changes in the cost of exporting from l to n.

The TEI can be a useful tool for identifying countries that are close competitors for export markets. It can also be applied in policy analysis in several other ways. For example, a foreign market, n, for which TEI_{nii} is relatively low is one for which a fall in export costs would be most beneficial for i's exporters.[33] Similarly, a relatively low value of TEI_{iil} indicates that i would benefit relatively more from a fall in import tariffs applied to producers from l because it implies a small effect on domestic producers and improved access to consumption goods and intermediate inputs that are not efficiently produced domestically. The TEI can also be employed as a simple indicator of the trade creation and trade diversion effects of a bilateral trade agreement. Specifically, the trade creation effect due to a reduction in trade barriers between n and l will be relatively large if the value of TEI_{nll} is relatively large, whereas trade diversion from a given country, i, will be relatively large if the value of TEI_{nil} is relatively large.

[33] This is because $\partial \ln(X_{ni})/\partial \ln(d_{ni}) = -\theta(1 - \pi_{ni}) + [\theta - (\sigma - 1)]\, \text{TEI}_{nii}$.

3.4 Uncovering the Sources of Comparative Advantage

Another use for RCA indexes is in investigating the causes of comparative advantage or in evaluating whether countries actually specialize according to measurable sources of comparative advantage – such as total factor productivity or factor endowments – as predicted by theory. To this end, an appropriate RCA index, such as the RBI or GBI, could be correlated with country- and product-specific variables expected to influence patterns of comparative advantage to test whether these factors have significant explanatory power. Such an exercise is suggested by Deardorff (2011) and is employed by Kowalski and Bottini (2011), though the latter employ a variant of the BI, which retains its shortcomings.

A related strategy is to take advantage of the form of (3) to directly estimate the effect of potential sources of comparative advantage on trade flows. Specifically, suppose one posits that T_i^k is a function of country- and product-specific variables and takes the form

$$\ln(T_i^k) = \alpha_i + \alpha^k + \sum_{\ell} \sum_{m} \alpha_{\ell m} L_{i\ell} M_m^k,$$

where L_i^ℓ is a measure of country-specific characteristic ℓ in country i, M_m^k is a measure of product-specific characteristic m for product k, and $\alpha_{\ell m}$ measures the importance of the interaction between these country- and product-specific characteristics in increasing producers' ability to deliver a product. For example, comparative advantage may be determined by the interaction of country-specific characteristics, such as factor endowments or the presence of particular institutions, and product characteristics, such as factor intensity or dependence on institutions, such as contract enforcement or access to financial markets, for which particular country-specific factors may be relevant.

In this case, equation (3) implies that the effect of these observable variables on comparative advantage and, in turn, on trade flows can be estimated via a regression of the form

$$\ln(X_{ni}^k) = \delta_{ni} + \delta_n^k + \sum_{\ell} \sum_{m} \delta_{\ell m} L_{i\ell} M_m^k + \varepsilon_{ni}^k,$$

where the estimate of δ_n^k is a consistent estimator of $\theta\alpha_{\ell m}$. Such an estimation strategy has been employed by Romalis (2004), Chor (2010), and CDK, among others, and is likely to continue to be a fruitful strategy in similar contexts.

3.5 Changes in Technology Over Time

RCA indexes have also been employed in analyses of technological change over time, for example in Proudman and Redding (2000) and Bahar et al. (2014). In such applications, changes in the RBI or GBI are valid indicators of changes in productivity *relative to changes for the reference product and country.* However, great care must be taken in interpreting the results of such an exercise, as changes in the index do not necessarily indicate changes in productivity levels for the country and product of interest, but may be due to changes for the reference product or country (or both). To see this, consider the ratio of GBI values for a given product in two periods:

$$\mathrm{GBI}^k_{i,t+1} \Big/ \mathrm{GBI}^k_{i,t} = \frac{T^k_{i,t+1}/T^{k_0}_{i,t+1}}{T^k_{i_0,t+1}/T^{k_0}_{i_0,t+1}} \Bigg/ \frac{T^k_{i,t}/T^{k_0}_{i,t}}{T^k_{i_0,t}/T^{k_0}_{i_0,t}} .$$

Thus, any change in the GBI between periods t and $t+1$ is potentially caused by changes in any combination of eight variables, making it difficult to draw conclusions regarding the meaning of such changes.

Further, it is unlikely that a more suitable index for across-time comparisons can be constructed. For example, consider what may seem to be a useful inter-temporal measure based on Proposition 2, replacing the reference country with a base time period:

$$\frac{X^k_{ni,t}/X^{k_0}_{ni,t}}{X^k_{ni,t_0}/X^{k_0}_{ni,t_0}} = \frac{T^k_{i,t}/T^{k_0}_{i,t}}{T^k_{i,t_0}/T^{k_0}_{i,t_0}} \times \frac{(d^k_{i,t})^{-\theta} X^k_{n,t}/\Phi^{k_0}_{n,t}}{(d^k_{i,t_0})^{-\theta} X^k_{n,t_0}/\Phi^{k_0}_{n,t_0}} .$$

Clearly this measure confounds changes in relative productivity with changes in market conditions over time. The RBI and GBI are able to isolate the effect of relative productivity on trade flows by comparing bilateral trade flows for a given product to trade flows from other countries of the same product to the same market (removing product- and market-specific effects of trade distortions) and to trade flows from the same country of other products (removing bilateral effects of trade distortions). However, this strategy cannot be implemented using trade flows from different time periods because, if technologies and/or distortions change over time, then so do market conditions in each destination, meaning that there is no suitable reference point by which to separate these effects. Instead, analyses of inter-temporal changes in comparative advantage will typically require a more sophisticated analysis which takes advantage of additional data, such as prices, independent measures of productivity, or information on factors of production.[34]

3.6 Summary

In this section, I have defined four new RCA-type measures, in addition to the existing BI and RBI. For ease of reference, Table 1 lists all of these indexes along with the empirical formula, value in the model, and a short description of the appropriate use or interpretation of each. The table also highlights that there are a number of RCA measures that are useful for different purposes. This list is not meant to be exhaustive; it is likely that other useful measures can be derived from this modelling framework, which are appropriate for additional objectives. The examples of this section merely demonstrate how simple and intuitive RCA measures can be derived from a common class of quantitative trade models and applied to many empirical investigations.

[34] See Levchenko and Zhang (2016) for a recent example of a structural approach to such a question.

Table 1: Summary of Useful RCA Indexes

Index	Section	Empirical Formula	Theoretical Value	Use/Interpretation
BI	3.1	$\frac{E_i^k/E^k}{E_i/E}$		Relative ability of i to produce k (if trade is frictionless).
BBI	3.1	$\frac{X_{ni}^k/X_n^k}{X_{ni}/X_n}$	$\frac{T_i^k(d_n^k)^{-\theta}/\Phi_n^k}{T_{ni}/\Phi_n}$	Relative ability of i to deliver product k to n.
BAI	3.3	$\frac{X_{ni}^k}{X_n^k} - \frac{X_{ni}}{X_n}$	$\frac{T_i^k(c_i d_{ni}^k)^{-\theta}}{\Phi_n^k} - \frac{T_{ni}(c_i d_{ni})^{-\theta}}{\Phi_n}$	Differential effect of change in trade barriers across products.
RBI	3.2	$e^{\hat{\delta}_i^k}$	$\frac{T_i^k/T_i^{k_0}}{T_{i_0}^k/T_{i_0}^{k_0}}$	Country's fundamental comparative advantage.
GBI	3.2	$\hat{\phi}_i^k$	$\frac{T_i^k/T_i^{k_0}}{T_{i_0}^k/T_{i_0}^{k_0}}$	Country's fundamental comparative advantage.
TEI	3.3	$\sum_{k=1}^k \frac{X_n^k}{X_n}\left(\text{BBI}_{ni}^k \times \text{BAI}_{nl}^k\right)$	$\propto \left(\frac{\partial \ln(X_{ni})}{\partial \ln(d_{nl})} - \frac{\partial \ln(\bar{X}_{ni})}{\partial \ln(d_{nl})}\right)$	Sensitivity of aggregate trade to changes in bilateral trade costs.

Notes: $\partial \ln(\bar{X}_{ni})/\partial \ln(d_{nl})$ denotes the hypothetical elasticity of X_{ni} with respect to d_{nl} if l were to have no comparative advantage in any product – i.e., if $\pi_{nl}^k = \pi_{nl}$, for all k.

4 Empirical Examples

Before concluding, it is useful to take a brief look at the data in light of the theoretical insights underpinning the indexes that I have defined. I consider two applications. First, I examine how well the prediction of Proposition 2 approximates the data. Second, I compute and compare measures of countries' fundamental patterns of comparative advantage within a heavily traded industry – motor vehicles.

I employ product-level trade data from the UN Comtrade database for the year 2003. The dataset contains trade flows among 130 countries, classified into 6-digit product categories according to the 1996 revision of the Harmonized Commodity Description and Coding Systems (HS). Because the theory suggests that the RCA measures discussed above are most appropriately applied to a range of products within similar industries, I conduct the analyses over products within 2-digit ISIC (revision 3) industries. To do this, I allocate HS categories to ISIC industries using the concordance from the U.N. Statistics Division.[35] I consider only the manufacturing industries (ISIC 15-36), which contain a total of 4,608 product categories. Table 2 provides a list of industries and the number of 4-digit and 6-digit HS product categories (denoted HS-4 and HS-6, respectively)

[35] This is available for free download from the following url: http://unstats.un.org/unsd/cr/registry/regdntransfer.asp?f=183.

in each industry.[36]

4.1 RCA Reversals

The basic insight of Proposition 2 is that it is possible to recover information about countries' fundamental patterns of comparative advantage from bilateral trade flows. An additional implication of Proposition 2 is the following:

Corollary 1. *Given the conditions necessary for Proposition 2, for any two destinations, n and n'; any two source countries, i and i'; and any two products, k and k',*

$$\frac{X^k_{ni}}{X^k_{ni'}} > \frac{X^{k'}_{ni}}{X^{k'}_{ni'}} \iff \frac{X^k_{n'i}}{X^k_{n'i'}} > \frac{X^{k'}_{n'i}}{X^{k'}_{n'i'}}.$$

In other words, for each pair of exporters, the ranking of $X^k_{ni}/X^k_{ni'}$ across products is the same for all destinations. This provides a testable prediction of the theory.

To evaluate the accuracy of this prediction, I compute the number of concordant pairs of the ratio $X^k_{ni}/X^k_{ni'}$ across products for each pair of destination countries and for each pair of source countries. Specifically, a pair is considered concordant if

$$\text{sgn}\left(\frac{X^k_{ni}}{X^k_{ni'}} - \frac{X^{k'}_{ni}}{X^{k'}_{ni'}}\right) = \text{sgn}\left(\frac{X^k_{n'i}}{X^k_{n'i'}} - \frac{X^{k'}_{n'i}}{X^{k'}_{n'i'}}\right),$$

and it is considered discordant (i.e., an RCA reversal) otherwise, unless there is a tie. A tie occurs if at least one of the sgn(·) terms is equal to zero or is undefined.[37]

I calculated the number of concordant and discordant pairs across all HS-6 and HS-4 product categories within each industry for all combinations of the 75 largest countries (by export volume) in the dataset.[38] Table 2 presents the percentage of pairs (not including ties) that are concordant for each industry.[39] There are a couple patterns that emerge from the table. First, the rankings of products are clearly strongly associated across countries, as Corollary 1 predicts, but this prediction does not hold exactly in the data. Second, as the theory suggests, the relationship seems to be stronger for more narrowly-defined products.

For HS-6 categories, between 65.3% and 76.2% of pairs are concordant, meaning that the ranking of relative exports in one market has a good deal of predictive power for the ranking in

[36] The concordance allocates each HS-6 category to a unique ISIC industry. For calculations involving HS-4 categories, I consider the whole category to fall within an industry if it is the parent of any HS-6 category in the industry. This leads to 35 of 1,072 HS-4 categories being duplicated across two or three industries.

[37] This occurs any time $X^k_{ni}X^{k'}_{ni'} - X^{k'}_{ni}X^k_{ni'} = 0$.

[38] The sample was restricted purely for computational efficiency. Adding additional smaller countries seemed to slightly increase the share of concordant pairs, if it had any significant effect at all.

[39] The vast majority of pairs – in excess of 98% for most industries when using HS-6 categories – are ties because of the extreme prevalence of zeros in the product-level bilateral trade data. However, because there are $(N(N-1)/2)^2K^j(K^j-1)/2$ possible pairs for each industry, there were still millions of non-ties, at the very least, for all industries other than Tobacco.

Table 2: Concordant Bilateral Trade Pairs by Industry

		Products		Conc. Pairs (%)		R^2	
ISIC	Sector Description	HS-4	HS-6	HS-4	HS-6	HS-4	HS-6
15	Food and beverages	119	422	72.5	76.2	0.90	0.91
16	Tobacco	2	6	65.8	73.0	1.00	1.00
17	Textiles	105	541	67.9	71.0	0.95	0.94
18	Wearing apparel, fur	42	241	64.8	67.4	0.97	0.96
19	Leather, leather products, and footwear	19	67	68.0	69.1	0.97	0.98
20	Wood products (excluding furniture)	25	69	69.3	72.2	0.99	0.99
21	Paper and paper products	29	120	67.8	70.4	0.98	0.98
22	Printing and publishing	13	36	66.2	67.3	0.97	0.95
23	Coke, refined petroleum, nuclear fuel	8	20	69.9	72.2	0.99	1.00
24	Chemicals and chemical products	198	879	68.6	73.6	0.91	0.91
25	Rubber and plastics products	29	121	65.1	67.3	0.98	0.97
26	Non-metallic mineral products	61	170	68.2	71.7	0.94	0.93
27	Basic metals	95	359	66.9	70.0	0.93	0.93
28	Fabricated metal products	68	221	64.6	66.9	0.95	0.94
29	Machinery not elsewhere classified	98	528	64.8	67.6	0.94	0.91
30	Office, accounting, computing machinery	7	37	64.3	67.1	0.98	0.95
31	Electrical machinery	25	134	62.8	65.3	0.98	0.97
32	Communication equipment	16	101	63.3	68.1	0.96	0.95
33	Medical, precision, and optical instruments	48	212	66.4	69.9	0.94	0.92
34	Motor vehicles	13	54	62.9	65.7	0.99	0.98
35	Other Transport equipment	28	81	67.5	73.4	0.92	0.92
36	Furniture, other manufacturing	65	189	71.2	72.2	0.98	0.99

Notes: $R^2 = 1 - \frac{\sum_n \sum_{i \neq n} \sum_k (X_{ni}^k - \hat{X}_{ni}^k)^2}{\sum_n \sum_{i \neq n} \sum_k (X_{ni}^k - \bar{X}_{ni}^k)^2}$, where $\hat{X}_{ni}^k = \hat{\phi}_{ni} \hat{\phi}_n^k \hat{\phi}_i^k$ is the predicted value of trade flows based on the GBI, and $\bar{X}_{ni}^k = \frac{1}{N(N-1)K} \sum_n \sum_{i \neq n} \sum_k X_{ni}^k$.

another market.[40] Overall, given the simplicity of the model, I find these results to be moderately encouraging for the usefulness of RCA indexes. However, when employing such an index, one should should consider several possible reasons why these measures are not closer to 100%. It could be due to deviations from the assumption regarding trade costs in equation (2) or the assumption that θ is constant across products within an industry. It could also reflect factors that give one country a comparative advantage in particular markets.[41] Finally, it could simply be due to randomness in the data, because of lumpiness in transactions or measurement error, for example.

One way to ameliorate the effects of randomness is to aggregate across products. However, the insights of Proposition 2 caution against this, and aggregation is also likely to exacerbate the other issues discussed above. The results using HS-4 categories confirm this. For every industry, the share of concordant pairs is smaller than at the 6-digit level. I also performed the calculation across aggregated 2-digit ISIC industries and found the share to be even lower: 64.4%. This suggests that, while there is a tradeoff, RCA measures should typically be calculated at lowest level of aggregation

[40] It should be noted that two lists of uncorrelated random numbers would be expected to have 50% concordant pairs. To place these results on a familiar scale, these values correspond to values of Goodman and Kruskal's γ, a measure of pairwise rank correlation lying in $[-1, 1]$, of between 0.31 and 0.52.

[41] For example, compared with the U.S., Germany may have a comparative advantage in autos versus steel in France, which has similar fuel efficiency standards, but the U.S. may have a comparative advantage in autos in Canada.

that is practical.

Another way of evaluating the assumptions underlying Proposition 2 is to directly examine how well equation (3) is able to fit the data. As a simple measure of this, Table 2 also reports R^2 values based on the parameter estimates underlying the GBI, which imposes the form of (3) but not the strict ranking implied by Proposition 2. The values are at least 0.90 for every industry, indicating that the vast majority of the variance in X_{ni}^k is explained by exporter-product, product-market, and exporter-market effects. This suggests that, where there are RCA reversals in the data, they tend to be between products for which comparative advantage is relatively weak, and that the reversals are reasonably idiosyncratic. Though this evidence is merely suggestive, it is consistent with the measurement error explanation.

4.2 Fundamental Patterns of Comparative Advantage in Auto Manufacturing

To get a sense of the empirical properties of the measures of countries' fundamental patterns of comparative advantage, defined in Section 3.2, I compute values of the RBI and GBI for all HS-6 products within the motor vehicles manufacturing industry – the most heavily traded 2-digit ISIC industry – and for all of the 122 countries with positive trade flows in the industry.[42] For comparison, I also compute values of the BI. The values of each index for the first 34 HS-6 products and 16 largest countries (by GDP) are presented in Tables 5–7 in Appendix E. All values presented are relative to mid-sized spark ignition autos (HS 870323) produced in the U.S. For each index, the value $RCA^{\frac{1}{\theta}}$ is presented, where "RCA" represents the index of choice, and I take $\theta = 4$ in line the the estimate of Waugh (2010). In this form, the values can be interpreted as measures of relative productivity.

To summarize some of the interesting patterns in these results, I present the value of each index for the U.S. relative to Germany (Table 3) and for the U.S. relative to China (Table 4). The products are ranked in ascending order of U.S. comparative advantage as measured by the GBI. The overall patterns that emerge seem reasonable. For example, compared to the U.S., Germany has a strong comparative advantage in diesel automobiles and a strong comparative disadvantage in large, spark-ignition trucks, and China has a strong comparative advantage in components.

Comparing the different measures, a couple patterns emerge. While the GBI and RBI produce similar results, both in terms of magnitudes and product rankings, they are much more highly correlated for Germany-U.S. comparative advantage than for China-U.S. comparative advantage. This is consistent with a sample-selection problem in the RBI when the dataset contains a large number of zero-valued observations. For China, nearly 70% of potential product-level trade flows are zero, compared to 41% for Germany and 50% for the U.S.

Looking more closely at the GBI and RBI for Germany-U.S. comparative advantage, the largest discrepancies occur for products in which one of the countries' exports are relatively concentrated

[42] This moderate-sized sample was just beyond the capabilities of Stata's regression command, given Stata's matrix size limit, so I computed both the GBI and RBI using Matlab, following the algorithm of Guimarães and Portugal (2010) for the RBI. Computation of the RBI was slowed significantly by the unbalanced trade flow matrices caused by dropping zero values. Computation took approximately 2 seconds for the GBI and 4 minutes for the RBI.

Table 3: RCA: Germany vs. U.S.A. (ISIC 34)

		GBI		CDK		BRCA	
HS Code	Description	Rank	RCA	Rank	RCA	Rank	RCA
870331	Autoes, diesel, <1500cc	1	2.99	6	1.32	1	4.92
870332	Autos, diesel, 1500-2500cc	2	2.51	2	1.76	2	3.60
870510	Mobile cranes	3	1.87	5	1.37	4	2.01
870322	Autos, spark, 1000-1500cc	4	1.82	7	1.28	3	2.22
870710	Bodies for passenger vehicles	5	1.42	47	0.47	8	1.49
870210	Diesel powered buses	6	1.41	3	1.46	9	1.44
870423	Diesel trucks, >20 tonnes	7	1.40	1	1.97	7	1.50
870323	Autos, spark, 1500-3000cc	8	1.39	8	1.25	15	1.30
870860	Non-driving axles for vehicles	9	1.35	23	0.95	5	1.53
871690	Trailer parts, NES	10	1.30	13	1.20	13	1.34
870540	Mobile concrete mixers	11	1.24	15	1.14	6	1.52
870831	Mounted brake linings	12	1.24	9	1.25	11	1.36
871610	Trailers, housing or camping	13	1.22	29	0.88	24	1.03
871639	Trailers, NES, for goods transport	14	1.19	11	1.21	16	1.28
870324	Autos, spark, >3000cc	15	1.16	16	1.14	20	1.17
870893	Clutches for vehicles	16	1.16	21	0.99	12	1.34
840999	Parts for diesel engines	17	1.12	18	1.05	14	1.30
870790	Bodies for tractors, buses, trucks	18	1.12	32	0.84	19	1.19
870120	Road tractors for semi-trailers	19	1.09	17	1.07	18	1.19
870421	Diesel trucks, <5 tonnes	20	1.08	4	1.44	17	1.24
870880	Shock absorbers for vehicles	21	1.07	24	0.95	22	1.06
870422	Diesel trucks, 5-20 tonnes	22	1.07	10	1.21	21	1.14
870870	Wheels for vehicles	23	1.05	22	0.98	27	1.00
870894	Steering columns for vehicles	24	1.03	14	1.18	32	0.99
870892	Mufflers for vehicles	25	1.01	20	0.99	31	0.99
870840	Transmissions for vehicles	26	1.00	28	0.89	34	0.96
870839	Other brake system parts	27	1	19	1	26	1
870333	Autos, diesel, >2500cc	28	0.99	12	1.20	10	1.41
871631	Tanker trailers,semi-trailers	29	0.98	25	0.94	29	0.99
870810	Bumpers and parts for vehicles	30	0.92	38	0.77	35	0.95
840820	Engines, diesel	31	0.91	39	0.77	25	1.02
840991	Parts for spark engines	32	0.91	36	0.79	28	0.99
870290	Buses, not diesel powered	33	0.89	41	0.69	42	0.75
870891	Radiators for vehicles	34	0.89	26	0.94	33	0.96
870829	Parts of bodies for vehicles	35	0.88	27	0.90	41	0.82
870590	Special purpose vehicles	36	0.88	30	0.86	23	1.04
840734	Engines, reciprocating, >1000cc	37	0.86	33	0.81	40	0.82
870530	Fire fighting vehicles	38	0.85	31	0.85	39	0.82
870899	Motor vehicle parts, NES	39	0.80	37	0.77	37	0.89
870850	Drive axles for vehicles	40	0.80	42	0.68	43	0.73
870821	Safety belts for vehicles	41	0.77	34	0.80	44	0.71
871640	Trailers, semi-trailers, NES	42	0.76	40	0.71	30	0.99
870600	Motor vehicle chassis, w/ engine	43	0.76	43	0.65	38	0.84
860900	Cargo containers	44	0.70	35	0.79	36	0.93
870520	Mobile drilling derricks	45	0.67	45	0.55	46	0.57
840733	Engines, reciprocating, 250-1000cc	46	0.61	50	0.32	48	0.41
870321	Autos, spark, <1000cc	47	0.59	48	0.46	45	0.65
870431	Spark trucks, <5 tonnes	48	0.47	44	0.56	49	0.35
870390	Automobiles, NES	49	0.39	51	0.27	47	0.47
870432	Spark trucks, >5 tonnes	50	0.34	46	0.50	50	0.35
870490	Trucks, NES	51	0.25	49	0.38	51	0.29
870310	Snowmobiles, golf cars	52	0.17	53	0.14	53	0.21
840732	Engines, reciprocating, 50-250cc	53	0.16	52	0.26	52	0.26
840731	Engines, reciprocating, <50cc	54	0	54	0	54	0
75/25 percentile ratio:			1.55		1.71		1.59

		GBI	CDK	BRCA
	GBI	1.00		
Spearman rank correlation:	CDK	0.84	1.00	
	BRCA	0.94	0.84	1.00

Table 4: RCA: China vs. U.S.A.(ISIC 34)

		GBI		CDK		BRCA	
HS Code	Description	Rank	RCA	Rank	RCA	Rank	RCA
860900	Cargo containers	1	5.32	1	2.26	1	6.81
840732	Engines, reciprocating, 50-250cc	2	2.95	16	0.94	2	6.14
871690	Trailer parts, NES	3	2.50	7	1.26	4	2.49
870870	Wheels for vehicles	4	2.22	6	1.28	6	2.39
870831	Mounted brake linings	5	2.12	4	1.47	5	2.40
870860	Non-driving axles for vehicles	6	1.91	17	0.94	7	2.02
870891	Radiators for vehicles	7	1.74	22	0.88	8	1.86
870839	Other brake system parts	8	1.72	8	1.08	9	1.81
870892	Mufflers for vehicles	9	1.52	18	0.93	17	1.42
870893	Clutches for vehicles	10	1.45	10	1.02	10	1.73
870310	Snowmobiles, golf cars	11	1.42	31	0.68	12	1.61
840733	Engines, reciprocating, 250-1000cc	12	1.42	37	0.59	27	1.10
871640	Trailers, semi-trailers, NES	13	1.33	27	0.77	11	1.68
870821	Safety belts for vehicles	14	1.31	21	0.88	20	1.31
870880	Shock absorbers for vehicles	15	1.27	25	0.85	16	1.43
870290	Buses, not diesel powered	16	1.25	5	1.45	14	1.50
840731	Engines, reciprocating, <50cc	17	1.21	29	0.75	3	2.72
840999	Parts for diesel engines	18	1.16	36	0.62	13	1.54
870829	Parts of bodies for vehicles	19	1.14	23	0.86	28	1.09
870510	Mobile cranes	20	1.13	9	1.07	15	1.47
871639	Trailers, NES, for goods transport	21	1.10	13	0.96	26	1.15
870810	Bumpers and parts for vehicles	22	1.09	35	0.64	25	1.20
870899	Motor vehicle parts, NES	23	1.09	26	0.77	18	1.37
870210	Diesel powered buses	24	1.08	3	1.47	19	1.32
840991	Parts for spark engines	25	1.03	33	0.65	21	1.24
870322	Autos, spark, 1000-1500cc	26	1.00	28	0.76	23	1.22
870894	Steering columns for vehicles	27	1	12	1	30	1
871610	Trailers, housing or camping	28	0.89	38	0.57	44	0.68
870421	Diesel trucks, <5 tonnes	29	0.85	11	1.02	33	0.92
870590	Special purpose vehicles	30	0.82	30	0.73	24	1.21
870423	Diesel trucks, >20 tonnes	31	0.82	2	1.69	31	0.93
870600	Motor vehicle chassis, w/ engine	32	0.81	45	0.50	22	1.23
870850	Drive axles for vehicles	33	0.79	41	0.55	39	0.80
870790	Bodies for tractors, buses, trucks	34	0.78	42	0.55	35	0.89
870431	Spark trucks, <5 tonnes	35	0.76	15	0.95	42	0.71
870840	Transmissions for vehicles	36	0.76	47	0.46	38	0.81
870321	Autos, spark, <1000cc	37	0.74	43	0.53	37	0.82
870520	Mobile drilling derricks	38	0.74	14	0.96	32	0.93
870331	Autos, diesel, <1500cc	39	0.72	24	0.86	36	0.88
870540	Mobile concrete mixers	40	0.70	32	0.67	29	1.03
870422	Diesel trucks, 5-20 tonnes	41	0.69	19	0.93	34	0.90
870332	Autos, diesel, 1500-2500cc	42	0.67	34	0.65	40	0.75
871631	Tanker trailers,semi-trailers	43	0.66	39	0.57	41	0.73
870710	Bodies for passenger vehicles	44	0.47	50	0.36	45	0.53
840820	Engines, diesel	45	0.45	48	0.40	46	0.53
870120	Road tractors for semi-trailers	46	0.44	44	0.52	47	0.52
870323	Autos, spark, 1500-3000cc	47	0.43	52	0.33	48	0.49
870530	Fire fighting vehicles	48	0.43	46	0.47	43	0.70
840734	Engines, reciprocating, >1000cc	49	0.38	51	0.33	51	0.41
870390	Automobiles, NES	50	0.35	49	0.37	49	0.49
870333	Autos, diesel, >2500cc	51	0.34	40	0.55	50	0.42
870324	Autos, spark, >3000cc	52	0.25	53	0.31	52	0.34
870432	Spark trucks, >5 tonnes	53	0.22	20	0.92	53	0.29
870490	Trucks, NES	54	0.11	54	0.27	54	0.21
75/25 percentile ratio:			1.88		1.73		2.05

		GBI	CDK	BRCA
	GBI	1.00		
Spearman rank correlation:	CDK	0.67	1.00	
	BRCA	0.94	0.67	1.00

on a single destination. For example, 90% of German exports of passenger vehicle bodies (HS 870710) go to Hungary, and 97% of U.S. exports of medium-sized diesel trucks (HS 870421) go to Canada. This occurs because the RBI, which is a function of log trade flows, tends to infer a greater comparative advantage for products for which a country exports a similar amount to many destinations, while the GBI, which is a function of trade flows in levels, depends primarily on the total value of exports.

Overall, these results reinforce the practical considerations discussed in Section 3.2. While it is not possible to draw firm conclusions about which RCA measure is more accurate without independent knowledge of relative productivity, given the insights of Santos Silva and Tenreyro (2006) regarding the properties log-linear OLS and Poisson PML estimators, it seems reasonable to advise that, where a discrepancy exists, the GBI is likely to be the more robust measure, especially if there are a large number of zeros in the data. Finally, it is interesting the note the similarity between the GBI and BI in both examples. This is not overly surprising, given that both are proportional to product-level exports in levels, but it indicates that, in this example, correctly controlling for importer-product and bilateral effects has only a moderate, though certainly non-negligible, effect on the overall pattern of RCA. While caution should always be used in interpreting values of the atheoretic BI, this similarity suggests that the BI may be a reasonable tool for a first pass at the data. To summarize, the following seems to be a reasonable rule of thumb regarding measures of fundamental comparative advantage: For a quick and dirty inspection of the data, the BI is probably fine; for small datasets with few zeros, the RBI is a reasonable and convenient choice; for all other all other cases, the GBI is recommended.

5 Concluding Remarks

This paper applies insights from a widely-used class of quantitative trade models to explore the usefulness of measures of revealed comparative advantage. This exercise makes clear the conditions under which RCA measures are informative and demonstrates that there is no single ideal index that is appropriate for all tasks. The theory implies two basic principles that should guide future uses of RCA indexes in empirical analyses. First, data on bilateral trade flows – not data aggregated across importers – should generally be used because it allows for the effects of comparative advantage to be isolated from other bilateral and market-specific effects of trade distortions. Second, since comparative advantage is, by nature, a relative value, an RCA index must be a function of trade flows relative to an appropriate point of reference. This reference point must be appropriate for the particular use of the RCA index, and it must not change across products or countries for which values of the index are to be compared.

Guided by the model, I have proposed several indexes that are appropriate for specific purposes. The regression-based measure of CDK and the Gravity-Based Index are theoretically consistent measures of relative productivity. The Bilateral Additive Index is the appropriate measure of comparative advantage when evaluating its effect on the response of product-level trade flows to changes in trade barriers. And, the Trade Elasticity Index, which is equal to the weighted covariance of the BAI and the Bilateral Balassa Index across products, measures the responsiveness of aggregate trade flows to changes in trade barriers. These indexes are easily computed, straightforward to interpret, and theoretically appropriate for their respective tasks, which have often attracted the use of more traditional, atheoretic RCA measures in the past. These, and perhaps other similarly-derived measures, should prove to be valuable tools to be employed in applied academic and policy-oriented international trade analyses.

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Appendix

A Proofs

Lemma 1 Following the methods of Eaton and Kortum (2002), it is straightforward to show that

$$P_i^k = \gamma^k (\Phi_i^k)^{-\frac{1}{\theta}},$$

where γ^k is defined in footnote 9. In autarky, $\Phi_n^k = T_i^k c_i^{-\theta}$, which implies that the autarky price index of k in i is

$$\bar{P}_i^k = \gamma^k (T_i^k)^{-\frac{1}{\theta}} \bar{c}_i,$$

where a "bar" indicates the value of an endogenous variable in autarky. This implies that

$$\frac{\bar{P}_i^k / \bar{P}_i^{k'}}{\bar{P}_{i'}^k / \bar{P}_{i'}^{k'}} = \left(\frac{T_i^k / T_i^{k'}}{T_{i'}^k / T_{i'}^{k'}} \right)^{-\frac{1}{\theta}}.$$

The value of this price ratio is less than unity if and only if the term in parentheses is greater than unity.

□

Proposition 1 From equation (3) and the definition of Φ_n^k, with frictionless trade,

$$X_{ni}^k = \frac{T_i^k c_i^{-\theta}}{\Phi^k} X_n^k,$$

where $\Phi^k = \sum_i T_i^k c_i^{-\theta}$. This implies that

$$\frac{E_i^k / E_i^{k'}}{E_{i'}^k / E_{i'}^{k'}} = \frac{T_i^k / T_i^{k'}}{T_{i'}^k / T_{i'}^{k'}},$$

which, by Lemma 1, is greater than unity if and only if i has a comparative advantage in producing k.

□

Proposition 2 This result follows immediately from equation (3), which implies that

$$\frac{X_{ni}^k / X_{ni}^{k'}}{X_{ni'}^k / X_{ni'}^{k'}} = \frac{T_i^k / T_i^{k'}}{T_{i'}^k / T_{i'}^{k'}},$$

which, by Lemma 1, is greater than unity if and only if i has a comparative advantage in producing k.

□

B Models Consistent with RCA

In this Appendix, I describe a set of models for which the results of this paper hold. Specifically, I will show that Propositions 1 and 2 hold in each model. As in the text, I suppress the sector superscript, so it should be understood that all terms are sector-specific.

B.1 Armington

Suppose that each of the assumptions of the baseline model holds, with the following exceptions:

1. Each country produces a unique variety of each product, denoted by the pair (k, i).

2. The elasticity of substitution across varieties, η^k, is constant across products and equal to η.

3. The marginal cost of producing variety (k, i) and shipping it to n is given by

$$c_{ni}^k = (T_i^k)^{\frac{1}{1-\eta}} c_i d_{ni}^k,$$

Because varieties are now defined by country of origin, expenditure on variety (k, i) is given by

$$x_{ni}^k = \left(\frac{p_{ni}^k}{P_n^k}\right)^{1-\eta} X_n^k,$$

where p_{ni}^k is the price of (k, i) in n and $P_n^k = \left(\sum_i (p_{ni}^k)^{1-\eta}\right)^{1/(1-\eta)}$. Perfect competition implies that $p_{ni}^k = c_{ni}^k$, which implies that equations (3) - (5) hold as in the baseline model, with θ replaced by $\eta - 1$, and that

$$P_i^k = \left(\sum_i T_i^k (c_i d_{ni}^k)^{1-\eta}\right)^{\frac{1}{1-\eta}},$$

which implies that the autarky price index of k in i is

$$\bar{P}_i^k = (T_i^k)^{\frac{1}{1-\eta}} \bar{c}_i,$$

where a "bar" indicates the value of an endogenous variable in autarky. This implies that

$$\frac{\bar{P}_i^k / \bar{P}_i^{k'}}{\bar{P}_{i'}^k / \bar{P}_{i'}^{k'}} = \left(\frac{T_i^k / T_i^{k'}}{T_{i'}^k / T_{i'}^{k'}}\right)^{\frac{1}{1-\eta}}.$$

Thus, Lemma 1 holds in this model. Because equation (3) holds in this model, the proofs of Propositions 1 and 2 are identical to those for the baseline model.

B.2 Bertrand Competition

Using the results of Bernard et al. (2003), it is trivial to show to that all of the expressions of this paper hold up to a constant scale factor if firms engage in Bertrand limit pricing and if the productivity of the first and second most productive firms in country i for producing variety (j,k,ω) is distributed according to

$$F_i^{jk}(z_1,z_2)=\left[1+T_i^{jk}(z_2^{-\theta^j}-z_1^{-\theta^j})\right]e^{-T_i^{jk}z_2^{-\theta^j}}.$$

B.3 Monopolistic Competition

The models with perfect and Bertrand competition assume that there is a fixed set of product varieties and technologies for producing them. In the Armington case, each country produces a single variety of each product, while in the models of Eaton and Kortum (2002) and Bernard et al. (2003), producers in each country can produce all varieties. In the case of monopolistic competition, each firm produces a unique variety, so ω indexes a firm as well as a variety. In this case, rather than normalizing the measure of varieties of each product to 1, as in the baseline model, the measure of varieties available in each market is determined by the measure of firms that ship their good there. I denote this measure Ω_n^k.

In what follows, I first show that the results of the baseline model hold when the set of potential varieties and technologies is fixed and then discuss the implications of allowing them to be determined endogenously through firm entry.[43]

B.3.1 Homogeneous Firms

I first consider a generalization of the homogeneous firms model of Krugman (1980). Suppose that each of the assumptions of the baseline model holds, with the following exceptions:

1. Each variety is produced by a single, monopolistically competitive firm.
2. The elasticity of substitution across varieties, η^k, is constant across products and equal to η.
3. The marginal cost of producing variety (k,ω) in i and shipping it to n is given by

$$c_{ni}^k(\omega)=c_{ni}^k=c_i d_{ni}^k,$$

4. There is a measure N_i^k of firms in i that can produce varieties of k.

Expenditure on variety (k,ω) is given by

$$x_n^k(\omega)=\left(\frac{p_n^k(\omega)}{P_n^k}\right)^{1-\eta}X_n^k.$$

where $p_n^k(\omega)$ is the price of (k,ω) in n and $P_n^k=\left(\int_{\Omega_n^k}p_n^k(\omega)^{1-\eta}\right)^{\frac{1}{1-\eta}}$. Profit maximization implies that firms charge a constant markup over marginal cost so that

$$p_n^k(\omega)=\frac{\eta}{\eta-1}c_{ni}^k.$$

[43] Arkolakis et al. (2012) refer these cases as "restricted entry" and "free entry", respectively.

These two results imply that equations (3) - (5) hold as in the baseline model, with T_i^k replaced by N_i^k and θ replaced by $\eta - 1$, and that

$$P_i^k = \left(\sum_i N_i^k (c_i d_{ni}^k)^{1-\eta} \right)^{\frac{1}{1-\eta}},$$

which, in autarky is given by

$$\bar{P}_i^k = (N_i^k)^{\frac{1}{1-\eta}} \bar{c}_i.$$

This implies that

$$\frac{\bar{P}_i^k / \bar{P}_i^{k'}}{\bar{P}_{i'}^k / \bar{P}_{i'}^{k'}} = \left(\frac{N_i^k / N_i^{k'}}{N_{i'}^k / N_{i'}^{k'}} \right)^{\frac{1}{1-\eta}}.$$

Thus, Lemma 1 holds in this model. Because equation (3) holds in this model, the proofs of Propositions 1 and 2 are identical to those for the baseline model.

B.3.2 Heterogeneous Firms

I now consider a generalization of the heterogeneous firms model of Melitz (2003), with Pareto distributed firm productivity and restricted entry, as in Chaney (2008). Suppose that each of the assumptions of the baseline model holds, with the following exceptions:

1. Each variety is produced by a single, monopolistically competitive firm.
2. The elasticity of substitution across varieties, η^k, is constant across products and equal to η.
3. There is a measure N_i^k firms in i that can produce varieties of k.
4. Firm productivity, $Z_i^k(\omega)$, is a random variable distributed according to

$$F_i^k(z) = 1 - (z/\underline{z})^{-\theta}, \quad z > \underline{z} > 0$$

5. Shipping goods from i to n requires paying a fixed exporting cost of f_{ni}^k, where $f_{ni}^k = f_{ni} f_n^k$ and $f_{nn}^k = 0, \forall n, k$.

Expenditure on variety (k, ω) is given by

$$x_n^k(\omega) = \left(\frac{p_n^k(\omega)}{P_n^k} \right)^{1-\eta} X_n^k.$$

where $p_n^k(\omega)$ is the price of (k, ω) in n and $P_n^k = \left(\int_{\Omega_n^k} p_n^k(\omega)^{1-\eta} \right)^{\frac{1}{1-\eta}}$. Profit maximization implies that firms charge a constant markup over marginal cost so that $p_n^k(\omega) = \bar{m} c_{ni}^k(\omega)$, where $\bar{m} = \frac{\eta}{\eta-1}$.

These two results imply that profits from selling in n for a firm with productivity z are given by

$$\Pi_{ni}^k(z) = \left(\frac{\bar{m}c_i d_{ni}^k}{zP_n^k}\right)^{1-\eta} \frac{X_n^k}{\eta}.$$

A firm from i will sell in n as long as $\Pi_{ni}^k(z) > f_{ni}^k$, so the lowest productivity firm from i that sells a variety of k in n has productivity

$$\bar{z}_{ni}^k = \max\left\{\frac{\bar{m}c_i d_{ni}^k}{P_n^k}\left(\frac{\eta f_{ni}^k}{X_n^k}\right)^{\frac{1}{\eta-1}}, \underline{z}\right\}.$$

I assume that the model parameters are such that $\bar{z}_{ni}^k > \underline{z}$, for all $n \neq i$. However, the assumption that $f_{nn}^k = 0$ implies that $\bar{z}_{nn}^k = \underline{z}$, for all n. Thus, the analogue of (3) in this model is

$$\pi_{ni}^k \equiv \frac{X_{ni}^k}{X_n^k} = \frac{N_i^k (c_i d_{ni}^k)^{-\theta} (f_{ni}^k)^{1-\frac{\theta}{\eta-1}}}{\sum_i N_i^k (c_i d_{ni}^k)^{-\theta} (f_{ni}^k)^{1-\frac{\theta}{\eta-1}}}, \tag{13}$$

for $n \neq i$. In autarky, the price index for product k is given by

$$\bar{P}_i^k = \tilde{\gamma}(N_i^k)^{\frac{1}{1-\eta}} \bar{c}_i,$$

where $\tilde{\gamma}$ is a collection of constants.[44] Note that this result relies on the assumption that $f_{nn}^k = 0$, which implies that all potential firms sell in the domestic market. Otherwise, $\bar{P}_i^k$ would depend on the values of f_{nn}^k and $\bar{X}_n^k$.

This implies that

$$\frac{\bar{P}_i^k/\bar{P}_i^{k'}}{\bar{P}_{i'}^k/\bar{P}_{i'}^{k'}} = \left(\frac{N_i^k/N_i^{k'}}{N_{i'}^k/N_{i'}^{k'}}\right)^{\frac{1}{1-\eta}}.$$

Thus, Lemma 1 holds in this model. Using (13) and following the proofs for the baseline case, it is trivial to show that Propositions 1 and 2 hold in this model.

B.3.3 Free Entry

Both cases of monopolistic competition have assumed that the set of firms and technologies does not depend on trade flows. However, in the standard Melitz (2003) model, firms decide whether to pay a fixed cost to create a unique variety and draw a productivity for producing it with full knowledge of worldwide factor endowments, fixed export costs, and iceberg trade costs. As a result, the set of potential varieties and technologies is endogenous and depends on trade costs. This implies that comparative advantage is not a fixed state of the world, due to exogenous technologies or factor endowments, as suggested by Definition 1. Instead, countries' effective ability to produce product k depends on the number of varieties it produces, and product-level price indexes depend on the level

[44] The constant $\tilde{\gamma} = \bar{m}\left(\frac{\theta}{\theta-(\eta-1)}\right)^{\frac{1}{1-\eta}} \underline{z}^{\frac{\theta}{\eta-1}-1}$.

of expenditure, creating a feedback mechanism that breaks the link between countries' apparent comparative advantage in a given equilibrium and autarky relative prices.

If, instead, one were to define comparative advantage as a country's relative measured productivity (including gains from variety) in a given equilibrium, then the results of this paper hold in the case of free entry as well. Further, all of the comparative statics discussed in Section 3 can be interpreted as "medium-term" effects, where production, employment, and trade flows have had time to respond to changes, but investments in the creation of new varieties and technologies have not yet come to fruition.

C RCA with Factor-Proportions-Based Comparative Advantage

In this Appendix, I consider an extension of the baseline model in which inter-product comparative advantage arises due to factor endowment differences. In the extended model, I relax the assumption that production of each product in a given country uses inputs in the same proportions but make somewhat more restrictive assumptions regarding production functions and preferences in order to preserve analytical tractability.[45] Instead, I assume the following:[46]

1. Each country is endowed with a measure $L_{m,i}$ of factor m, for $m = 1, ..., M$.
2. Each product is produced via a Cobb-Douglas production function, with factor shares that differ across products but are identical across countries, denoted α_m^k, where $\sum_{m=1}^{M} \alpha_m^k = 1$.
3. Consumers in every country have identical Cobb-Douglas preferences across product categories – i.e., $\tilde{\beta}_n^k = \tilde{\beta}^k$, and $\sigma \to 1$.

In this setting the cost-minimizing price of bundle of inputs is product specific, so (1) becomes

$$c_{ni}^k = \frac{c_i^k d_{ni}^k}{Z_i^k(\omega)},$$

where c_i^k is the minimum cost of a bundle of inputs used to produce a variety of product k. This implies that the autarky price index of k in i is

$$\bar{P}_i^k = \gamma^k (T_i^k)^{-\frac{1}{\theta}} \bar{c}_i^k,$$

where a "bar" indicates the value of an endogenous variable in autarky. This implies the following analogue of Lemma 1:

[45] Note that, as Deardorff (2000) points out, similar results hold locally when these functional form assumptions are relaxed.

[46] This extension draws on insights on the relationship between the factor content of trade and factor prices by Deardorff and Staiger (1988), Deardorff (2000), and Burstein and Vogel (2011).

Lemma 1′. *Country i has a comparative advantage in producing product k, compared to country i' and product k', if and only if*

$$\frac{T_i^k(\bar{c}_i^k)^{-\theta}}{T_{i'}^k(\bar{c}_{i'}^k)^{-\theta}} > \frac{T_i^{k'}(\bar{c}_i^{k'})^{-\theta}}{T_{i'}^{k'}(\bar{c}_{i'}^{k'})^{-\theta}},$$

where comparative advantage is defined according to Definition 1.

To derive analogues of Propositions 1 and 2, note that the Cobb-Douglas production functions imply that

$$c_i^k = \tilde{\alpha}^k \prod_{m=1}^{M} w_{m,i}{}^{\alpha_m^k},$$

where $\tilde{\alpha}^k$ is a collection of constants, and $w_{m,i}$ is the price of factor m in country i. The production functions also imply that

$$\begin{aligned} w_{m,i}L_{m,i} &= \sum_k \alpha_m^k Y_i^k \\ &= \sum_k \alpha_m^k X_i^k + \sum_k \alpha_m^k (Y_i^k - X_i^k) \\ &= \eta_m X_i + w_{m,i}\mathrm{FCT}_{m,i}, \end{aligned}$$

where $Y_i^k = \sum_n X_{ni}^k$ denotes total output of k in i. The last equality relies on the assumptions of identical Cobb-Douglas preferences and defines $\eta_m = \sum_k \alpha_m^k \tilde{\beta}^k$ and the factor content of trade:

$$\begin{aligned} \mathrm{FCT}_{m,i} &\equiv (w_{m,i})^{-1} \sum_k \alpha_m^k (Y_i^k - X_i^k) \\ &= (w_{m,i})^{-1} \sum_k \alpha_m^k (E_i^k - M_i^k). \end{aligned}$$

Note that in autarky, $\mathrm{FCT}_{m,i} = 0$, and

$$\bar{w}_{m,i}L_{m,i} = \eta_m \bar{X}_i,$$

which implies that

$$\frac{\bar{w}_{m,i}}{w_{m,i}} = \frac{\bar{X}_i}{X_i}\tilde{\mathcal{L}}_{m,i},$$

where

$$\tilde{\mathcal{L}}_{m,i} = \frac{L_{m,i} - \mathrm{FCT}_{m,i}}{L_{m,i}}$$

represents the relative trade-adjusted supply of factor m.

All of this implies that

$$\frac{\bar{c}_i^k / c_i^k}{\bar{c}_i^{k'} / c_i^{k'}} = \prod_{m=1}^{M} \tilde{\mathcal{L}}_{m,i}{}^{\alpha_m^k - \alpha_m^{k'}},$$

which, together with Lemma 1′, directly implies the following analogues of Propositions 1 and 2:

Propostion 1′. *If $d_{ni}^k = 1$, for all n, i, and k, then for any two countries, i and i', and any two products, k and k', each country exports relatively more, when corrected by relative trade-adjusted factor supplies, of the product for which it has a comparative advantage:*

$$\frac{E_i^k}{E_{i'}^k}\prod_{m=1}^{M}\left(\frac{\tilde{\mathcal{L}}_{m,i}}{\tilde{\mathcal{L}}_{m,i'}}\right)^{-\theta\alpha_m^k} > \frac{E_i^{k'}}{E_{i'}^{k'}}\prod_{m=1}^{M}\left(\frac{\tilde{\mathcal{L}}_{m,i}}{\tilde{\mathcal{L}}_{m,i'}}\right)^{-\theta\alpha_m^{k'}} \iff \frac{T_i^k(\bar{c}_i^k)^{-\theta}}{T_{i'}^k(\bar{c}_{i'}^k)^{-\theta}} > \frac{T_i^{k'}(\bar{c}_i^{k'})^{-\theta}}{T_{i'}^{k'}(\bar{c}_{i'}^{k'})^{-\theta}}.$$

Propostion 2′. *For any set of technologies, $\{T_i^k\}$; trade costs, $\{d_{ni}\}$ and $\{d_n^k\}$; factor endowments, $\{L_{m,i}\}$; factor shares, $\{\alpha_m^k\}$; and expenditure shares, $\{\tilde{\beta}^k\}$; and for any destination, n; any two source countries, i and i'; and any two products, k and k'; each source country exports relatively more to n, when corrected by relative trade-adjusted factor supplies, of the product for which it has a comparative advantage:*

$$\frac{X_{ni}^k}{X_{ni'}^k}\prod_{m=1}^{M}\left(\frac{\tilde{\mathcal{L}}_{m,i}}{\tilde{\mathcal{L}}_{m,i'}}\right)^{-\theta\alpha_m^k} > \frac{X_{ni}^{k'}}{X_{ni'}^{k'}}\prod_{m=1}^{M}\left(\frac{\tilde{\mathcal{L}}_{m,i}}{\tilde{\mathcal{L}}_{m,i'}}\right)^{-\theta\alpha_m^{k'}} \iff \frac{T_i^k(\bar{c}_i^k)^{-\theta}}{T_{i'}^k(\bar{c}_{i'}^k)^{-\theta}} > \frac{T_i^{k'}(\bar{c}_i^{k'})^{-\theta}}{T_{i'}^{k'}(\bar{c}_{i'}^{k'})^{-\theta}}.$$

The proofs of Propositions 1′ and 2′ follow analogously to those for Propositions 1 and 2.

D What if There is No Domestic Trade Data?

Because data on domestic trade flows (X_{nn}^k) are often not as readily available as data on international trade flows, in this appendix, I consider measures that require only the latter. Consider the expression for trade flows as a share of destination market imports, rather than total expenditure. For a given product, this is given by

$$\tilde{\pi}_{ni}^k \equiv \frac{X_{ni}^k}{M_n^k} = \frac{T_i^k(c_i d_{ni})^{-\theta}}{\tilde{\Phi}_n^k},$$

$\tilde{\Phi}_n^k = \sum_{i\neq n} T_i^k(c_i d_{ni})^{-\theta}$. Because d_n^k has the same effect on all foreign sellers of k in n, it disappears from this expression. The corresponding expression for aggregate trade flows is

$$\tilde{\pi}_{ni} \equiv \frac{X_{ni}}{M_n} = \frac{T_{ni}(c_i d_{ni})^{-\theta}}{\tilde{\Phi}_n},$$

$\tilde{\Phi}_n = \sum_{i\neq n} T_{ni}(c_i d_{ni})^{-\theta}$. Note that T_{ni} in this expression is the same value as that in (5), which implies that π_{ni} still depends on the values of Φ_n^k and Φ_n.

The GBI and RBI do not require data on domestic trade flows. It is also straightforward to define versions of the BBI and BAI which do not require such data, i.e.

$$\widetilde{\text{BBI}}_{ni}^k \equiv \frac{X_{ni}^k/M_n^k}{X_{ni}/M_n} = \frac{T_i^k/\tilde{\Phi}_n^k}{T_{ni}/\tilde{\Phi}_n}$$

and

$$\widetilde{\text{BAI}}_{nl}^{k} \equiv \frac{X_{nl}^{k}}{M_{n}^{k}} - \frac{X_{nl}}{M_{n}} = (c_i d_{ni})^{-\theta}\left[\frac{T_i^k}{\tilde{\Phi}_n^k} - \frac{T_{ni}}{\tilde{\Phi}_n}\right].$$

The interpretation of these measures is essentially unchanged except that they now measure i's ability to provide k to n relative to the rest of world, *excluding* n. In fact, since d_n^k drops out of the analysis, the comparison is even a bit more straightforward.

However, the question remains whether these measures are useful regarding questions of the responsiveness of trade flows to trade barriers, as are BBI and BAI. It turns out that this is not generally the case. Consider the partial elasticity of X_{ni}^k with respect to d_{nl} holding constant M_n^k (rather than X_n, as before)[47]

$$\begin{aligned}\frac{\partial \ln(X_{ni}^k)}{\partial \ln(d_{nl})} &= \theta\tilde{\pi}_{nl} + [\theta - (\sigma-1)](\pi_{nl}^k - \pi_{nl}) \\ &= \theta\tilde{\pi}_{nl} + [\theta - (\sigma-1)]\text{BAI}_{nl}^k.\end{aligned}$$

While the aggregate component of the elasticity does not depend on domestic trade flows, the product-specific component still depends on BAI, not $\widetilde{\text{BAI}}$. This is because this terms reflects country l's effect on relative prices in n, which depends on l's share of n's consumption, not only its imports.

However, $\widetilde{\text{BAI}}$ may be a reasonable approximation of BAI under certain conditions. The relationship between the two measures is as follows:

$$\begin{aligned}\text{BAI}_{nl}^k &= \tilde{\pi}_{nl}^k \frac{M_n^k}{X_n^k} - \tilde{\pi}_{nl}\frac{M_n}{X_n} \\ &= \frac{M_n}{X_n}\widetilde{\text{BAI}}_{nl}^k + \left(\frac{M_n^k}{X_n^k} - \frac{M_n}{X_n}\right)\tilde{\pi}_{nl}^k \\ &= \frac{M_n}{X_n}\widetilde{\text{BAI}}_{nl}^k - \tilde{\pi}_{nl}^k \text{BAI}_{nn}^k.\end{aligned}$$

Thus, $\widetilde{\text{BAI}}$ is generally an overestimate of BAI by the inverse of n's overall import share. However, data on X_n is often available, so this can be corrected even when data on X_{nn}^k is not available. More concerning is that it will also overestimate the value of BAI for products for which n has a comparative disadvantage, measured as BAI_{nn}^k. As a result, for destinations which have relatively high import shares or relatively weak patterns of comparative advantage, $\widetilde{\text{BAI}}$ is a good approximation of BAI, but caution should be used in regard to imports of large and/or heavily specialized countries.[48]

[47]This is essentially a compensated elasticity, where X_n is adjusted to hold M_n fixed. This exercise allows us to ignore features of the domestic market in n as much as possible.

[48]It may be reasonable to use measures of n's comparative advantage in other markets to partially correct for this bias. French (2016a), in a conceptually similar exercise, uses the full set of bilateral product-level trade flows to estimate the effects of patterns of comparative advantage on the responsiveness of trade flows to trade costs. However, this comes at the cost of giving up the simplicity of utilizing easily calculated measures of RCA.

The same principles apply to calculating the TEI, which can be expressed as

$$\text{TEI}_{nil} = \sum_{k=1}^{k} \frac{M_n^k}{M_n} \left(\widetilde{\text{BBI}}_{ni}^k \times \text{BAI}_{nl}^k \right).$$

This implies that, while $\widetilde{\text{BBI}}$ can be used in calculating TEI without issue, replacing BAI with $\widetilde{\text{BAI}}$ leads to a measure that deviates from the true value of TEI to the extent that BAI_{nn}^k covaries with BBI_{ni}^k.

E Additional Tables

Table 5: GBI for HS6 Categories in Motor Vehicle Manufacturing (ISIC 34)

HS Code	Description	AUS	BRA	CAN	CHN	DEU	ESP	FRA	GBR	IND	ITA	JPN	KOR	MEX	NLD	RUS	USA
840731	Engines, reciprocating, <50cc	0.53	0	0.28	2.80	0	0.21	0.24	0.42	0.95	1.52	0.60	0.33	0.09	0.71	0.45	1
840732	Engines, reciprocating, 50-250cc	0.57	0.60	0.71	6.83	0.12	0.23	0.18	0.18	0.97	1.11	0.65	0.42	0.26	0.53	0.61	1
840733	Engines, reciprocating, 250-1000cc	1.32	1.19	2.78	3.28	0.44	0.56	0.74	1.16	2.35	2.25	2.64	1.46	0.24	1.25	3.93	1
840734	Engines, reciprocating, >1000cc	1.19	0.85	1.09	0.89	0.62	0.52	0.49	0.81	0.27	0.62	0.63	0.30	0.85	0.42	1.08	1
840820	Engines, diesel	0.48	0.81	0.37	1.05	0.66	0.66	0.86	0.59	0.52	0.83	0.54	0.23	0.45	0.57	1.23	1
840991	Parts for spark engines	0.70	0.87	0.97	2.37	0.66	0.50	0.64	0.58	1.30	0.79	0.76	0.40	0.84	0.65	1.00	1
840999	Parts for diesel engines	0.72	0.99	0.75	2.68	0.81	0.54	0.81	0.74	1.58	0.94	0.62	0.49	0.88	0.93	1.19	1
860900	Cargo containers	0.66	0.25	0.66	12.33	0.51	0.52	0.64	0.65	1.37	0.82	0.29	0.68	0.85	0.80	1.85	1
870120	Road tractors for semi-trailers	0.39	0.82	1.49	1.03	0.79	0.54	0.85	0.37	0.76	0.49	0.35	0.20	1.24	1.60	0.86	1
870210	Diesel powered buses	0.59	1.15	2.18	2.51	1.02	0.83	0.91	0.97	1.71	0.85	0.85	1.08	0.77	1.34	1.05	1
870290	Buses, not diesel powered	0.73	0.23	1.21	2.90	0.64	1.12	0.46	0.64	1.69	0.66	0.85	0.78	0.21	0.78	1.76	1
870310	Snowmobiles, golf cars	0.40	0	1.06	3.29	0.12	0.36	0.32	0.36	0.71	0.35	0.49	0.18	0.12	0.45	0.70	1
870321	Autos, spark, <1000cc	0.65	0.66	1.06	1.71	0.43	0.85	1.07	0.57	2.41	0.65	0.92	1.00	0.43	0.78	0.71	1
870322	Autos, spark, 1000-1500cc	0.57	1.52	0.69	2.32	1.31	1.95	1.82	1.33	2.51	2.06	1.76	1.91	0.34	1.21	2.69	1
870323	Autos, spark, 1500-3000cc	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
870324	Autos, spark, >3000cc	0.87	0.08	1.18	0.57	0.84	0.32	0.33	0.69	0.40	0.79	0.74	0.59	0.67	0.39	0.28	1
870331	Autoes, diesel, <1500cc	2.42	2.17	2.09	1.66	2.16	2.57	2.79	2.37	2.97	2.67	2.48	2.74	0.68	2.30	0	1
870332	Autos, diesel, 1500-2500cc	1.00	1.41	0.43	1.56	1.81	1.67	1.93	1.53	1.23	1.80	1.72	1.64	2.39	1.66	0.97	1
870333	Autos, diesel, >2500cc	0.40	0.33	0.77	0.79	0.72	0.41	0.42	0.44	0.61	0.54	0.81	0.77	0.15	0.41	0.27	1
870390	Automobiles, NES	0.64	0.26	0.36	0.81	0.28	0.44	0.36	0.33	1.24	0.46	0.85	0.19	0.17	0.71	0.15	1
870421	Diesel trucks, <5 tonnes	0.52	0.94	0.48	1.96	0.78	0.96	0.94	0.75	1.05	1.28	0.85	0.83	1.65	0.68	0.57	1
870422	Diesel trucks, 5-20 tonnes	0.68	0.77	1.20	1.61	0.77	0.65	0.79	0.67	1.04	1.20	0.83	0.45	1.31	1.19	0.99	1
870423	Diesel trucks, >20 tonnes	0.39	1.22	1.97	1.89	1.01	0.95	0.95	0.44	0.55	0.77	0.86	0.24	1.27	1.80	1.67	1
870431	Spark trucks, <5 tonnes	0.52	0.68	1.85	1.76	0.34	0.62	0.55	0.45	0.56	0.60	0.60	0.37	1.28	0.50	1.25	1
870432	Spark trucks, >5 tonnes	0.11	0.09	0.32	0.52	0.24	0.33	0.36	0.49	0.53	0.58	0.17	0.23	1.22	0.88	1.23	1
870490	Trucks, NES	0.33	0	0.69	0.26	0.18	0.45	0.38	0	0.66	0.81	0.15	0.27	0	0.58	0	1
870510	Mobile cranes	0.49	0.25	0.75	2.63	1.35	0.67	0.54	0.81	0.85	0.87	0.80	0.44	0.49	1.35	1.52	1
870520	Mobile drilling derricks	0.98	0	1.35	1.71	0.48	0.71	0.83	0	0.42	0.97	0.28	0.20	0.35	0	1.24	1
870530	Fire fighting vehicles	0.37	0.34	1.23	0.99	0.61	0.55	0.70	0.60	0	1.12	0.24	0.40	0	0.72	0.96	1
870540	Mobile concrete mixers	0.51	0.59	1.41	1.63	0.90	0.62	0.59	0.48	0.60	1.55	0.90	0.51	0.52	1.19	1.69	1
870590	Special purpose vehicles	0.51	0.20	0.94	1.90	0.63	0.55	0.66	0.30	0.61	1.11	0.41	0.29	0.40	0.79	1.01	1
870600	Motor vehicle chassis, w/ engine	0.30	1.07	0.63	1.87	0.55	0.65	0.32	0.39	1.33	0.61	0.51	0.36	0.41	0.75	0.34	1
870710	Bodies for passenger vehicles	0.68	0.73	1.12	1.10	1.02	0.38	0.54	0.72	0.73	0.75	0.54	0.50	0.66	0.44	2.66	1
870790	Bodies for tractors, buses, trucks	0.83	1.44	1.59	1.82	0.81	0.59	1.06	0.62	0.43	1.48	0.53	0.55	0.88	1.15	1.50	1

Table 6: RBI for HS6 Categories in Motor Vehicle Manufacturing (ISIC 34)

HS Code	Description	AUS	BRA	CAN	CHN	DEU	ESP	FRA	GBR	IND	ITA	JPN	KOR	MEX	NLD	RUS	USA
840731	Engines, reciprocating, <50cc	1.86	0	1.42	2.26	0	0.50	0.47	0.76	1.72	1.47	0.64	0.74	0.16	1.27	0.64	1
840732	Engines, reciprocating, 50-250cc	1.56	0.73	1.60	2.86	0.21	0.39	0.32	0.44	1.40	1.29	0.74	0.46	0.37	0.89	0.53	1
840733	Engines, reciprocating, 250-1000cc	1.21	0.88	1.91	1.78	0.25	0.60	0.48	0.72	1.67	1.17	0.73	0.69	1.31	0.74	1.14	1
840734	Engines, reciprocating, >1000cc	2.06	1.38	1.32	1.01	0.64	0.55	0.59	0.78	0.82	0.90	0.77	0.53	1.64	0.79	1.02	1
840820	Engines, diesel	1.27	1.15	1.07	1.22	0.62	0.59	0.68	1.02	1.17	1.13	0.72	0.46	0.86	0.80	1.20	1
840991	Parts for spark engines	1.02	1.01	0.98	1.98	0.63	0.52	0.49	0.61	1.48	0.90	0.69	0.42	0.80	0.83	0.64	1
840999	Parts for diesel engines	1.18	1.13	0.91	1.88	0.83	0.87	0.84	1.02	1.51	1.22	0.61	0.62	0.73	1.40	0.96	1
860900	Cargo containers	1.53	0.47	1.27	6.85	0.63	0.90	0.70	0.74	2.16	1.19	0.35	0.72	1.13	1.24	1.45	1
870120	Road tractors for semi-trailers	1.14	1.76	1.13	1.56	0.85	0.79	0.86	0.65	1.50	0.85	0.44	0.44	1.68	1.82	1.17	1
870210	Diesel powered buses	3.32	3.01	2.18	4.45	1.16	1.64	1.18	1.56	3.45	1.51	1.65	1.83	1.27	1.98	1.57	1
870290	Buses, not diesel powered	2.91	0.90	2.35	4.40	0.55	1.44	0.52	0.90	3.36	1.09	0.95	1.24	0.77	1.28	1.70	1
870310	Snowmobiles, golf cars	0.90	0	1.36	2.05	0.11	0.44	0.26	0.48	1.26	0.39	0.30	0.26	0.31	0.42	0.64	1
870321	Autos, spark, <1000cc	1.53	0.95	1.79	1.60	0.36	0.80	0.67	0.65	2.80	0.75	0.73	1.04	0.56	0.70	0.74	1
870322	Autos, spark, 1000-1500cc	1.90	2.07	1.39	2.30	1.02	2.04	1.65	1.37	3.17	1.82	1.66	2.25	0.70	1.33	2.49	1
870323	Autos, spark, 1500-3000cc	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
870324	Autos, spark, >3000cc	1.58	0.30	1.42	0.95	0.91	0.42	0.40	0.84	0.74	0.81	0.68	0.67	0.68	0.50	0.40	1
870331	Autos, diesel, <1500cc	1.97	2.25	2.75	2.62	1.06	1.91	1.87	1.34	3.13	2.04	1.09	1.94	0.85	1.46	0	1
870332	Autos, diesel, 1500-2500cc	1.68	1.45	1.05	1.98	1.40	1.85	1.49	1.52	2.20	1.67	1.18	1.75	2.00	1.67	0.87	1
870333	Autos, diesel, >2500cc	1.47	0.92	1.52	1.68	0.96	1.31	0.71	1.06	1.43	1.12	1.33	1.35	0.66	0.85	0.55	1
870390	Automobiles, NES	1.27	0.76	0.77	1.13	0.21	0.56	0.34	0.54	1.70	0.62	0.57	0.29	0.53	0.69	0.16	1
870421	Diesel trucks, <5 tonnes	2.13	2.46	2.17	3.08	1.15	2.14	1.55	1.55	3.18	2.33	1.77	1.88	2.02	1.72	1.15	1
870422	Diesel trucks, 5-20 tonnes	1.92	1.49	1.96	2.81	0.97	1.22	0.98	0.96	2.02	1.80	1.04	0.61	1.29	1.79	1.24	1
870423	Diesel trucks, >20 tonnes	1.38	2.70	3.23	5.10	1.57	1.86	1.24	1.08	2.00	1.76	1.12	0.85	2.05	2.82	2.30	1
870431	Spark trucks, <5 tonnes	1.81	1.38	2.48	2.87	0.45	1.36	0.78	0.72	2.49	1.04	0.85	0.58	1.66	0.99	1.06	1
870432	Spark trucks, >5 tonnes	0.93	0.40	2.28	2.79	0.40	0.92	0.47	0.82	1.77	0.94	0.29	0.46	1.87	1.18	1.26	1
870490	Trucks, NES	1.41	0	1.63	0.82	0.31	0.79	0.49	0	1.67	0.90	0.24	0.38	0	0.94	0	1
870510	Mobile cranes	1.60	0.64	1.48	3.25	1.09	1.00	0.59	0.89	1.40	1.22	0.60	0.73	0.74	1.64	1.34	1
870520	Mobile drilling derricks	2.99	0	5.29	2.90	0.44	1.16	1.18	0	1.83	1.79	0.49	0.82	0.83	0	1.10	1
870530	Fire fighting vehicles	1.23	0.86	1.69	1.42	0.68	0.99	0.69	0.72	0	1.54	0.30	0.54	0	1.13	1.69	1
870540	Mobile concrete mixers	2.93	2.30	2.68	2.03	0.91	0.95	0.61	0.80	0.93	2.06	0.56	0.89	0.88	1.50	1.89	1
870590	Special purpose vehicles	1.44	0.55	1.59	2.21	0.69	0.80	0.75	0.46	1.11	1.43	0.38	0.45	0.81	1.05	1.24	1
870600	Motor vehicle chassis, w/ engine	0.82	1.75	1.15	1.52	0.52	1.06	0.31	0.44	1.75	0.68	0.41	0.34	0.54	0.76	0.42	1
870710	Bodies for passenger vehicles	1.39	0.82	1.30	1.10	0.38	0.53	0.44	0.84	1.58	0.74	0.37	0.49	0.65	0.61	1.07	1
870790	Bodies for tractors, buses, trucks	1.77	2.71	1.53	1.66	0.67	0.99	0.82	0.73	0.87	1.35	0.50	0.59	1.04	1.22	1.14	1

Table 7: BI for HS6 Categories in Motor Vehicle Manufacturing (ISIC 34)

HS Code	Description	AUS	BRA	CAN	CHN	DEU	ESP	FRA	GBR	IND	ITA	JPN	KOR	MEX	NLD	RUS	USA
840731	Engines, reciprocating, <50cc	0.85	0	0.55	5.57	0	0.48	0.58	0.90	1.84	3.43	1.16	0.67	0.18	1.33	0.77	1
840732	Engines, reciprocating, 50-250cc	0.73	0.85	0.72	12.55	0.20	0.36	0.40	0.28	1.60	1.78	1.05	0.75	0.27	0.80	0.76	1
840733	Engines, reciprocating, 250-1000cc	0.65	0.81	1.98	2.24	0.32	0.41	0.54	0.84	1.58	1.41	1.89	1.10	0.18	0.80	1.60	1
840734	Engines, reciprocating, >1000cc	0.86	0.81	1.04	0.84	0.63	0.53	0.54	0.82	0.25	0.66	0.61	0.30	0.82	0.43	0.76	1
840820	Engines, diesel	0.45	0.96	0.36	1.08	0.78	0.83	1.11	0.69	0.58	1.04	0.60	0.25	0.44	0.66	0.99	1
840991	Parts for spark engines	0.67	0.91	0.95	2.53	0.77	0.62	0.75	0.65	1.38	0.94	0.82	0.45	0.82	0.75	0.82	1
840999	Parts for diesel engines	0.89	1.13	0.77	3.15	1.00	0.74	0.99	0.90	1.89	1.21	0.73	0.59	0.91	1.13	1.22	1
860900	Cargo containers	0.82	0.30	0.69	13.90	0.72	0.78	0.90	0.89	1.79	1.20	0.36	0.81	0.89	1.13	1.72	1
870120	Road tractors for semi-trailers	0.55	0.83	1.03	1.06	0.92	0.68	1.02	0.42	0.85	0.58	0.36	0.21	0.89	1.78	1.01	1
870210	Diesel powered buses	0.86	1.16	1.49	2.69	1.11	0.96	0.99	1.04	2.24	0.95	0.91	1.13	0.55	1.44	1.38	1
870290	Buses, not diesel powered	0.94	0.26	0.95	3.07	0.57	0.90	0.37	0.54	2.10	0.53	0.86	0.83	0.17	0.65	2.26	1
870310	Snowmobiles, golf cars	0.44	0	1.03	3.29	0.16	0.47	0.40	0.45	0.78	0.42	0.54	0.20	0.11	0.57	0.67	1
870321	Autos, spark, <1000cc	0.55	0.70	0.93	1.68	0.50	1.09	1.33	0.68	2.81	0.77	0.91	0.98	0.38	0.92	0.59	1
870322	Autos, spark, 1000-1500cc	0.70	1.61	0.55	2.50	1.71	2.70	2.48	1.69	3.23	2.71	1.85	1.98	0.28	1.60	2.96	1
870323	Autos, spark, 1500-3000cc	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
870324	Autos, spark, >3000cc	1.05	0.09	1.55	0.69	0.90	0.31	0.32	0.77	0.45	0.80	0.90	0.71	0.88	0.40	0.27	1
870331	Autos, diesel, <1500cc	1.73	2.96	1.01	1.79	3.79	5.38	5.25	4.14	4.56	4.63	2.84	3.35	0.44	3.90	0	1
870332	Autos, diesel, 1500-2500cc	0.80	1.59	0.27	1.53	2.77	2.95	3.20	2.30	1.65	2.90	1.82	1.79	1.68	2.54	1.03	1
870333	Autos, diesel, >2500cc	0.50	0.39	0.44	0.86	1.09	0.74	0.71	0.68	0.87	0.87	0.94	0.87	0.10	0.64	0.36	1
870390	Automobiles, NES	0.62	0.32	0.46	1.00	0.36	0.59	0.47	0.41	1.56	0.61	1.04	0.23	0.21	0.94	0.26	1
870421	Diesel trucks, <5 tonnes	0.64	0.96	0.34	1.88	0.95	1.28	1.18	0.89	1.29	1.60	0.85	0.84	1.20	0.83	0.63	1
870422	Diesel trucks, 5-20 tonnes	0.94	0.89	1.06	1.84	0.87	0.78	0.92	0.75	1.28	1.38	0.93	0.51	1.17	1.32	1.28	1
870423	Diesel trucks, >20 tonnes	0.55	1.15	1.39	1.90	1.16	1.21	1.12	0.50	0.58	0.90	0.93	0.26	0.92	1.99	1.74	1
870431	Spark trucks, <5 tonnes	0.58	0.61	1.43	1.45	0.27	0.44	0.42	0.34	0.50	0.44	0.51	0.31	1.00	0.37	1.11	1
870432	Spark trucks, >5 tonnes	0.13	0.09	0.36	0.59	0.27	0.31	0.38	0.55	0.62	0.60	0.19	0.26	1.38	0.89	1.78	1
870490	Trucks, NES	0.67	0	0.51	0.44	0.22	0.57	0.48	0	1.13	0.94	0.27	0.41	0	0.74	0	1
870510	Mobile cranes	0.70	0.30	0.61	3.00	1.54	0.78	0.66	0.92	0.98	1.01	0.89	0.50	0.40	1.49	2.21	1
870520	Mobile drilling derricks	1.31	0	1.00	1.90	0.44	0.60	0.68	0	0.42	0.78	0.31	0.21	0.26	0	1.67	1
870530	Fire fighting vehicles	0.57	0.41	0.86	1.42	0.63	0.55	0.75	0.65	0	1.15	0.33	0.56	0	0.72	1.30	1
870540	Mobile concrete mixers	0.83	0.71	1.07	2.10	1.17	0.77	0.74	0.55	0.95	1.92	1.15	0.72	0.35	1.33	2.62	1
870590	Special purpose vehicles	0.74	0.28	0.79	2.47	0.80	0.71	0.85	0.36	0.89	1.39	0.50	0.40	0.33	0.95	1.68	1
870600	Motor vehicle chassis, w/ engine	0.41	1.25	0.32	2.52	0.65	0.78	0.43	0.45	1.91	0.74	0.68	0.47	0.23	0.87	0.47	1
870710	Bodies for passenger vehicles	0.66	0.78	0.77	1.09	1.15	0.52	0.77	0.92	0.88	1.09	0.55	0.55	0.54	0.63	2.96	1
870790	Bodies for tractors, buses, trucks	0.84	1.61	1.53	1.83	0.91	0.75	1.21	0.71	0.49	1.76	0.58	0.58	0.85	1.29	1.14	1