Estimating Import Demand and Export Supply Elasticities[*]

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Abstract

The objective of this paper is to provide estimates of import demand and export supply elasticities for around 4200 goods (six digit of the Harmonized System) in 117 countries. The empirical methodology follows the GDP function approach of Kohli (1991), which allows sufficient flexibility in terms of functional forms. Patterns found in the estimated elasticities are discussed. The estimates and their standard errors can be downloaded from a companion file.
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1 Introduction

Import demand and export supply elasticities are crucial inputs into many ex-ante analysis of trade reform. For example, to evaluate the impact of regional trade agreements on trade flows or customs revenue, one needs to first answer the question of how trade volumes would adjust to changes in policies, for which we need both the import and export elasticities. To provide estimates of overall protection including both tariff and non-tariff barriers one would need first to transform non-tariff barriers into ad-valorem equivalents, for which import elasticities are necessary. Moreover, if one needs to compare these overall levels of protection across different countries to answer questions, for example, related to market access barriers faced by developing country exporters, one would need to have a consistent set of trade elasticities, estimated using the same data and methodology.[1] These do not exist. The closest substitute and the one often used by trade economists is the survey of the empirical literature put together by Stern et al. (1976) more than 25 years ago. More recent attempts to provide disaggregate estimates of trade elasticities (although not necessarily price elasticities, but Armington or income elasticities) have been country specific and have mainly focused on the United States. This include Shiells, Stern and Deardorff (1986), Shiells, Roland-Holst and Reinert (1993), Blonigen and Wilson (1999), Marquez (1999, 2002, 2003), Broda and Weinstein (2003) and Gallaway, McDaniel and Rivera (2003).

The objective of this paper is to fill in this gap by providing a set of consistent estimates of import demand and export supply price elasticities for over 4200 products (at the 6 digit of the Harmonized System) in more than 100 countries.[2] The basic theoretical setup is the production based GDP function approach as in Kohli (1991) and Harrigan (1997). Imports and exports are considered as inputs and outputs of domestic production, for given exogenous world prices, productivity and endowments. This GDP function approach takes into account

[1] For an attempt to measure these barriers using Anderson and Neary's (2003) Multilateral Trade Restrictiveness Index, see Kee, Nicita and Olarreaga (2004).

[2] To our knowledge the only set of estimates at the 6 digit level of the Harmonized System that exist in the literature are the one provides by Panagariya *et al.* (2001) for the import demand elasticity faced by Bangladesh exporters of apparel.

general equilibrium effects associated with the reallocation of resources due to exogenous changes in prices or endowments, and thus has close links to trade theory. Moreover in a world where a significant share of growth in world trade is explained by vertical specialization (Yi, 2003), the fact that imports are treated as inputs into the revenue function –rather than as final consumption goods as in most of the previous literature– seems an attractive feature of this approach. While Kohli (1991) mainly focuses on aggregate import demand and export supply functions and Harrigan (1997) on industry level export supply functions, this paper modifies the GDP function approach to estimate good level import and export price elasticities.

A total of 363777 import demand elasticities have been estimated (and around a similar number of export supply elasticities will be estimated). The simple average across all countries and goods is about -4 and the median is -1.6. We found some interesting patterns in our estimated import demand elasticities that are consistent with theory. First, homogenous goods are shown to be more elastic than heterogenous goods. Second, there is evidence indicating that import demand is more elastic when estimated at the good level rather than the industry level. In other words, import demand elasticities decrease in magnitude as one aggregates the level of observation. Third, large countries tend to have more elastic import demands, due probability to a larger availability availability of domestic substitutes. Fourth, more developed countries tend to have less elastic import demands, mainly driven by a higher share of heterogenous goods in developed countries import demand. In sum, the estimated import demand elasticities exhibit a significant variation across countries and products – a nice property that has not been found in the existing literature.

Section 2 provides the theoretical framework, whereas section 3 describes the empirical strategy. Section 4 discuss data sources. Section 5 discusses the results and provides some patterns of trade elasticities across countries and goods. Section 6 concludes.

2 Theoretical Model – GDP Function Approach

The theoretical model follows Kohli's (1991) GDP function approach for the estimation of trade elasticities. We also draw on Harrigan's (1997) treatment of productivity terms in GDP functions. We will first derive the GDP, export supply and import demand functions for one country. However, assuming that the GDP function is common across all countries up to a country specific term –which controls for country productivity differences– it is then easily generalized to a multi-country setting in the next section.

Consider a small open economy in period t.[3] Let $\mathbf{S}^t \subset \mathbf{R}^{N+M}$ be the strictly convex production set in t of its net output vector $q^t = (q_1^t, q_2^t, ..., q_N^t)$ and factor endowment vector $v^t = (v_1^t, v_2^t, ..., v_M^t) \geq 0$. For the elements in the net output vector q^t, we adopt the convention that positive numbers denote outputs, which include exports, and negative numbers denote inputs, which include imported goods. We consider outputs for export as different products as output for domestic market. This could be motivated by higher product standard requirements in international markets.

Given the exogenous price vector $p^t = (p_1^t, p_2^t, ..., p_N^t) > 0$, perfect competition of firms would lead the economy to produce at a mixed of goods that maximizes its GDP in each period t :

$$G^t\left(p^t, v^t\right) \equiv \max_{q^t} \left\{p^t \cdot q^t : \left(q^t, v^t\right) \in \mathbf{S}^t\right\}. \tag{1}$$

Thus the GDP function, $G^t\left(p^t, v^t\right)$, is the maximum value of goods the economy can produce given exogenous prices, its factor endowments and technology in period t. It equals to the total value of output for exports and domestic consumption, minus the total value of imports ($q_n^t < 0$ for imports).

Assuming that production of each output n in period t is affected by some good specific (and later on country specific) Hicks-neutral productivity level, A_n^t, such that we can define $\tilde{q}^t = (\tilde{q}_1^t, \tilde{q}_2^t, ..., \tilde{q}_N^t)$ as the net output vector in t that is net of any Hicks-neutral productivity

[3] For a discussion of the relevance of the small country assumption when estimating trade elasticities, see Riedel (1988), Athukorala and Riedel (1994) and Panagariya *et al.* (2001).

gains:

$$q_n^t = A_n^t \tilde{q}_n^t, \ \forall n = 1, ..., N.$$

Define $\mathbf{A}^t = diag\left\{A_1^t, A_2^t, ..., A_N^t\right\}$, a N-dimensional diagonal matrix, then we can re-express Equation (1) as

$$\begin{aligned} G^t\left(p^t\mathbf{A}^t, v^t\right) &\equiv \max_{\tilde{q}^t}\left\{p^t\mathbf{A}^t \cdot \tilde{q}^t : \left(\tilde{q}^t, v^t\right) \in \tilde{\mathbf{S}}^t\right\} \Rightarrow \\ G^t\left(\tilde{p}^t, v^t\right) &= \max_{\tilde{q}^t}\left\{\tilde{p}^t \cdot \tilde{q}^t : \left(\tilde{q}^t, v^t\right) \in \tilde{\mathbf{S}}^t\right\} \end{aligned} \tag{2}$$

with $\tilde{p}^t = (\tilde{p}_1^t, \tilde{p}_2^t, ..., \tilde{p}_N^t)$ and $\tilde{\mathbf{S}}^t \subset \mathbf{R}^{N+M}$ is the product set that is defined over $\left(\tilde{q}^t, v^t\right)$. The advantage to differentiate q_n^t and $\tilde{q}_n^t$ is that the latter recognizes that productivity level is exogenous to the economy.[4] One way to interpret the multiplicative relationship of good prices and the associated productivity level is to define

$$\tilde{p}_n^t \equiv p_n^t A_n^t \tag{3}$$

as the productivity augmented price level of good n. This will be a useful addition in our empirical application as unit prices for the same tariff line will vary across different countries, which will then be explained by differences in productivity in different countries. In a recent study, Schott (forthcoming) successfully explains variation in unit value for similar products in different countries with GDP per capita levels. To the extent that GDP per capita is a proxy for labor productivity Schott's finding provides some evidence on our productivity augmented price level, $\tilde{p}^t$.

GDP function, $G^t\left(\tilde{p}^t, v^t\right)$, is homogeneous of degree one respect to good prices. Strictly convexity of $\mathbf{S}^t$ also ensures that the second order sufficient conditions are satisfied, such that $G^t\left(\tilde{p}^t, v^t\right)$ is twice differentiable and it is convex in $\tilde{p}^t$ and concave in v^t. By Envelope Theorem, the gradient of $G^t\left(\tilde{p}^t, v^t\right)$ with respect to $\tilde{p}^t$ is the unique output supply functions

[4] It could depend on past economic activities, such as lagged value of capital investment or R&D activities, but at the moment when firms are facing production choices, it is nevertheless considered as given.

of the economy in period t :

$$\frac{\partial G^t\left(\tilde{p}^t, v^t\right)}{\partial \tilde{p}_n^t} = \tilde{q}_n^t\left(\tilde{p}^t, v^t\right), \ \forall n = 1, ..., N. \tag{4}$$

Equation (4) implies that an increase in the price of exports would lead to an increase in GDP in period t, while an increase in import prices would reduce GDP in period t. Given that $G^t\left(\tilde{p}^t, v^t\right)$ is continuous and twice differentiable, and is convex and homogeneous of degree one with respect to prices, Euler Theorem also implies that the output supply functions, Equation (4), are homogenous of degree zero in prices, have non-negative own substitution effects and have symmetric cross substitution effects:

$$\frac{\partial^2 G^t\left(\tilde{p}^t, v^t\right)}{\partial \tilde{p}_n^t \partial \tilde{p}_i^t} = \begin{cases} \frac{\partial \tilde{q}_n^t\left(\tilde{p}^t, v^t\right)}{\partial \tilde{p}_n^t} \geq 0, \ \forall n = i \\ \frac{\partial \tilde{q}_n^t\left(\tilde{p}^t, v^t\right)}{\partial \tilde{p}_i^t} = \frac{\partial \tilde{q}_i^t\left(\tilde{p}^t, v^t\right)}{\partial \tilde{p}_n^t}, \ \forall n \neq i \end{cases}. \tag{5}$$

In other words, for every final good, including exports, an price increase *raises* output *supply*; for every input, including imports, an increase in prices *decreases* the *demand* of the input. In addition, an increase in the price of an imported input causes supply of an exported output to decrease, and an increase in the price of the exported output would increase the demand of the imported input in the same magnitude.

Thus with a well defined GDP function we could derive both the export supply functions and import demand functions, and as long as GDP function is twice differentiable, we could also derive the own and cross partial effects of exports and imports, and hence the export supply and import demand elasticities.

To implement the above GDP function empirically, let's assume, without loss of generality, that $G^t\left(\tilde{p}^t, v^t\right)$ follows a flexible translog functional form with respect to prices and endowments:

$$\begin{aligned}\ln G^t\left(\tilde{p}^t, v^t\right) &= a_{00}^t + \sum_{n=1}^{N} a_{0n}^t \ln \tilde{p}_n^t + \frac{1}{2}\sum_{n=1}^{N}\sum_{k=1}^{N} a_{nk}^t \ln \tilde{p}_n^t \ln \tilde{p}_k^t \\ &\quad + \sum_{m=1}^{M} b_{0m}^t \ln v_m^t + \frac{1}{2}\sum_{m=1}^{M}\sum_{l=1}^{M} b_{ml}^t \ln v_m^t \ln v_l^t \\ &\quad + \sum_{n=1}^{N}\sum_{m=1}^{M} c_{nm}^t \ln \tilde{p}_n^t \ln v_m^t, \end{aligned} \tag{6}$$

where all the translog parameters a, b and $c's$ are indexed by t to allow for changes over time. In order to make sure that Equation (6) satisfies the homogeneity and symmetry properties of a GDP function, we impose the following restrictions:

$$\sum_{n=1}^{N} a_{0n}^t = 1,\ \ \sum_{k=1}^{N} a_{nk}^t = \sum_{n=1}^{N} c_{nm}^t = 0,\ \ a_{nk}^t = a_{kn}^t,\ \ \forall n, k = 1, ..., N,\ \ \forall m = 1, ..., M. \tag{7}$$

Furthermore, if we assume that the GDP function is homogeneous of degree one in factor endowments, then we also need to impose the following restrictions:

$$\sum_{n=1}^{N} b_{0n}^t = 1,\ \ \sum_{k=1}^{N} b_{nk}^t = \sum_{m=1}^{M} c_{nm}^t = 0,\ \ b_{nk}^t = b_{kn}^t,\ \ \forall n, k = 1, ..., N,\ \ \forall m = 1, ..., M. \tag{8}$$

Given the translog functional form and the symmetry and homogeneity restrictions, the derivative of $\ln G^t\left(\tilde{p}^t, v^t\right)$ with respect to $\ln \tilde{p}_n^t$ gives us the share in GDP of good n at period $t:$

$$\begin{aligned} s_n^t\left(\tilde{p}^t, v^t\right) &= a_{0n}^t + \sum_{k=1}^{N} a_{nk}^t \ln \tilde{p}_k^t + \sum_{m=1}^{M} c_{nm}^t \ln v_m^t \\ &= a_{0n}^t + a_{nn}^t \ln \tilde{p}_n^t + \sum_{k\neq n} a_{nk}^t \ln \tilde{p}_k^t + \sum_{m=1}^{M} c_{nm}^t \ln v_m^t,\ \ \forall n = 1, ..., N, \end{aligned} \tag{9}$$

with $s_n^t > 0$ denoting the share of output of good n in GDP at time t, and $s_n^t < 0$ denotes share of import of good n in GDP in period t. From the above equation it could be shown that if good n is an exported output, then the export supply elasticity of good n is

$$\varepsilon_n^t \equiv \frac{\partial \ln q_n^t\left(\tilde{p}^t, v^t\right)}{\partial \ln p_n^t} = \frac{a_{nn}^t}{s_n^t} + s_n^t - 1 \geq 0,\ \forall s_n^t > 0, \tag{10}$$

with $a_{nn}^t \geq s_n^t\left(1 - s_n^t\right)$, ensuring that the price elasticity of export supply is non-negative (i.e., curvature conditions of the GDP function are satisfied to ensure GDP maximization). Similarly, if good n is an imported good, then the import demand elasticity of good n is

$$\varepsilon_n^t \equiv \frac{\partial \ln q_n^t\left(\tilde{p}^t, v^t\right)}{\partial \ln p_n^t} = \frac{a_{nn}^t}{s_n^t} + s_n^t - 1 \leq 0,\ \forall s_n^t < 0, \tag{11}$$

with $a_{nn}^t \geq s_n^t\left(1 - s_n^t\right)$, where $\left(-q_n^t\right) > 0$ denotes the quantity demanded of imports.[5] A nice property of this import demand elasticities from a trade theory point of view is that they are estimated keeping import prices and endowments constant –and not income as in the more usual log linear estimation (see Kohli, 1991, section 5.3 for a thorough discussion). Notice that for small $\left|s_n^t\right|$, the size of the import elasticity, ε_n^t, depends on the sign of a_{nn}^t:

$$\varepsilon_n^t \begin{cases} < -1 \text{ if } a_{nn}^t > 0, \\ = -1 \text{ if } a_{nn}^t = 0, \\ > -1 \text{ if } a_{nn}^t < 0. \end{cases}$$

This result is highly intuitive. If the share of imports in GDP is fixed $\left(a_{nn}^t = 0\right)$ with respect to the price of import, then the implied import demand is unitary elastic such that an increase in import price induces an equi-proportional decrease in import quantities and leaves the value of imports unchanged. If the share of imports in GDP, which is negative by construction, decreases with import price $\left(a_{nn}^t < 0\right)$, i.e., $-p_n^t q_n^t > 0$ increases with p_n^t, then the implied import demand is inelastic, so that an increase in import price induces a

[5] Let $z_n^t > 0$ be the quantity imported of good n in period t, and let $q_n^t = -z_n^t < 0$, then

$$\varepsilon_n^t \equiv \frac{\partial \ln z_n^t}{\partial \ln p_n^t} = \frac{\partial z_n^t}{\partial p_n^t}\frac{p_n^t}{z_n^t} = \frac{\partial q_n^t}{\partial p_n^t}\frac{p_n^t}{q_n^t} = \frac{\partial \ln q_n^t}{\partial \ln p_n^t} \leq 0.$$

less than proportionate decrease in import quantities. Finally, if the share of import in GDP increases with import prices $(a^t_{nn} > 0)$, then the implied import demand must be elastic such that an increase in the price of import induces a more than proportionate decrease in import quantity.[6]

Cross-price elasticities for import demand and export supply can be calculated in a similar fashion:

$$\varepsilon^t_{n,k} \equiv \frac{\partial \ln q^t_n \left(\tilde{p}^t, v^t\right)}{\partial \ln p^t_k} = \frac{a^t_{nk}}{s^t_n} + s^t_k, \ \forall n, k. \tag{12}$$

Finally, given that the elasticities are linear in the estimated coefficients, it is also possible to perform hypothesis testing on significance of the elasticities, base on the regression standard errors of a_{nn} :

$$S.E. \left(\varepsilon^t_{nc}\right) = \left| \frac{S.E. \left(a_{nn}\right)}{s^t_{nc}} \right|, \ \forall n.$$

Notice that by the design of the model, the estimated elasticities vary by good, country and year, since s^t_{nc} varies along all these dimensions.

3 Empirical Strategy

With data on output shares, unit values and factor endowments, Equation (9) is the basis of our estimation of export and import elasticities, over a panel of countries and years for each good. In principle, we could first estimate the own substitution effects, a^t_{nn}, for every good according to Equation (9), and apply Equations (10) and (11) to derive the implied estimated elasticities, since the own price elasticity is a linear function of own partial effects. However, there are literally thousands of goods traded among the countries in any given year. Moreover, on top of the thousands of traded commodities, there are even more non-traded commodities that also utilize countries' factor endowments and contribute to GDP in each

[6]Kohli (1991) found an inelastic demand for the aggregate US imports with $a_{nn} < 0$, while highly elastic demand for the durables and services imports of the US, with the corresponding $a_{nn} > 0$, when the aggregate import is broken down into 3 disaggregate groups.

country. Thus the number of explanatory variables in Equation (9) could easily exhausts our degrees of freedom or introduce serious collinearity problems.

Given that our objective is to estimate the own price effect, a^t_{nn}, for every good n, we re-express the multiple goods GDP function approach into a "two-good economy" producing goods n and $-n$:

$$G^t\left(\tilde{p}^t_n, \tilde{p}^t_{-n}, v^t\right) \equiv \max_{\tilde{q}^t}\left\{\tilde{p}^t_n\tilde{q}^t_n + \tilde{p}^t_{-n}\tilde{q}^t_{-n} : \left(\tilde{q}^t, v^t\right) \in \tilde{\mathbf{S}}^t\right\}, \tag{13}$$

where for every good n, we define $\tilde{p}^t_{-n}\tilde{q}^t_{-n} = \sum_{k\neq n,k=1}^{N} \tilde{p}^t_k\tilde{q}^t_k$ as the part of GDP that is originated from all other goods the economy produces. Provided that we have knowledge of the price of good $-n$, the translog specification of Equation (13) and the implied share equations for good n could then be applied to estimate the own price effect of every good n in this two good economy in a strict forward fashion with homogeneity and symmetry constraints imposed:

$$\begin{aligned}
\ln G^t\left(\tilde{p}^t_n, \tilde{p}^t_{-n}, v^t\right) &= a^t_{00} + a^t_{0n}\ln\tilde{p}^t_n + a^t_{0-n}\ln\tilde{p}^t_{-n} \\
&\quad + \frac{1}{2}a^t_{nn}\left(\ln\tilde{p}^t_n\right)^2 + \frac{1}{2}a^t_{-n-n}\left(\ln\tilde{p}^t_{-n}\right)^2 + a^t_{n-n}\ln\tilde{p}^t_n\ln\tilde{p}^t_{-n} \\
&\quad + \sum_{m=1}^{M} b^t_{0m}\ln v^t_m + \frac{1}{2}\sum_{m=1}^{M}\sum_{l=1}^{M} b^t_{ml}\ln v^t_m \ln v^t_l \\
&\quad + \sum_{m=1}^{M} c^t_{nm}\ln\tilde{p}^t_n\ln v^t_m + \sum_{m=1}^{M} c^t_{-nm}\ln\tilde{p}^t_{-n}\ln v^t_m, \qquad (14)\\
s^t_n\left(\tilde{p}^t_n, \tilde{p}^t_{-n}, v^t_c\right) &= a^t_{0n} + a^t_{nn}\ln\frac{\tilde{p}^t_n}{\tilde{p}^t_{-n}} + \sum_{m=1,m\neq k}^{M} c^t_{nm}\ln\frac{v^t_m}{v^t_k}, \ \forall n, c, t. \qquad (15)
\end{aligned}$$

To obtain $\tilde{p}^t_{-n}$, we need to impose more structure to the model. According to Caves, Christensen and Diewert (1982), if $G^t\left(\tilde{p}^t, v^t\right)$ follows a translog functional form as shown in Equation (6) or (14)and assuming that all the translog parameters are time invariant,

$a_{nk}^t = a_{nk}$, $\forall n, k, t$, then a Tornqvist price index,

$$P_T\left(p^t, p^{t-1}, v^t, v^{t-1}\right) \equiv \prod_{n=1}^{N} \left(\frac{p_n^t}{p_n^{t-1}}\right)^{\frac{1}{2}\left(s_n^t + s_n^{t-1}\right)}, \tag{16}$$

is the *exact price index for* $G^t\left(\tilde{p}^t, v^t\right)$, and is equal to the geometric mean of the theoretical GDP price index $P^t\left(p^t, p^{t-1}, v^{t-1}\right) \equiv \frac{G^{t-1}\left(\tilde{p}^t, v^{t-1}\right)}{G^{t-1}\left(\tilde{p}^{t-1}, v^{t-1}\right)}$ and $P^t\left(p^t, p^{t-1}, v^t\right) \equiv \frac{G^t\left(\tilde{p}^t, v^t\right)}{G^t\left(\tilde{p}^{t-1}, v^t\right)}$. Thus, in a two-good economy, the overall GDP deflator is the weighted average between the price changes of good n and the composite good $-n$:

$$\ln P_T\left(p^t, p^{t-1}, v^t, v^{t-1}\right) = \frac{1}{2}\left(s_n^t + s_n^{t-1}\right) \ln \frac{p_n^t}{p_n^{t-1}} + \frac{1}{2}\left(s_{-n}^t + s_{-n}^{t-1}\right) \ln \frac{p_{-n}^t}{p_{-n}^{t-1}}. \tag{17}$$

In other words, with information on the overall GDP deflator and the unit value of good n, we could infer the underlying price index of good $-n$, through Equation (17). Specifically, we can re-write Equation (17) to show that the change in the price index of the composite good $-n$ is the difference between the change in the overall GDP deflator of period t and the weighted change in the price of good n :

$$\begin{aligned} \ln \frac{p_{-n}^t}{p_{-n}^{t-1}} &= \frac{1}{\frac{1}{2}\left(s_{-n}^t + s_{-n}^{t-1}\right)} \left(\ln P_T\left(p^t, p^{t-1}, v^t, v^{t-1}\right) - \frac{1}{2}\left(s_n^t + s_n^{t-1}\right) \ln \frac{p_n^t}{p_n^{t-1}}\right), \\ \ln p_{-n}^t &= \ln p_{-n}^{t-1} + \frac{1}{\frac{1}{2}\left(s_{-n}^t + s_{-n}^{t-1}\right)} \left(\ln P_T\left(p^t, p^{t-1}, v^t, v^{t-1}\right) - \frac{1}{2}\left(s_n^t + s_n^{t-1}\right) \ln \frac{p_n^t}{p_n^{t-1}}\right) \end{aligned} \tag{18}$$

Thus, by normalizing prices of all goods, both n and $-n$, to 1 in the first year of our sample, we would be able to construct both price indexes for good n and $-n$ for each sample country c.

We estimate Equation (9) across countries and years and assume that the parameters of the GDP function are time invariant as required by the Tornqvist price index. Country subscript c is introduced to highlight the panel dimension in the estimation:

$$s_{nc}^t\left(\tilde{p}_{nc}^t, \tilde{p}_{-nc}^t, v_c^t\right) = a_{0n}^t + a_{0nc} + a_{nn} \ln \frac{\tilde{p}_{nc}^t}{\tilde{p}_{-nc}^t} + \sum_{m=1, m \neq k}^{M} c_{nm} \ln \frac{v_{mc}^t}{v_{kc}^t}, \ \forall n, c, t. \tag{19}$$

Notice that even though we assume that a_{nn} is common across all countries, the implied own price elasticities will still vary across countries, given that s_n^t is good, time and country specific (see Equations (11) and (10)). Equation (15) allows for country and year specific-effects for the constant term, which allows us to capture the shift in the GDP function that is due to productivity. We also impose homogeneity constraints with respect to endowments by setting $\sum_m c_{nm} = 1$ (i.e., all the endowment variables are measured relative to land endowment, v_k). Notice that in this two-good economy set up, there is a system of two equations for each good, one for n and one for $-n$. To avoid singularity in the estimation, we drop the equation for $-n$ such that no cross equation restrictions are necessary, and the estimation procedure is reduced to a single equation estimation. Also, note that separability is not imposed on the estimation –contrary to much of the existing literature– as the price of any other good $-n$ affects imports through the Tornqvist price index of $-n$. As argued by Winters (1984) separability is rarely observed in the data.[7]

For Equation (19) to be the first order condition of the GDP *maximization* program, second order conditions need to be satisfied (the Hessian matrix needs to be negative semi-definite). Such conditions are also known as the curvature conditions which ensure that the GDP function is smooth, differentiable, and convex with respect to output prices and concave with respect to input prices and endowments. This requires that the estimated export elasticities are positive and import elasticities are negative for all observations (see Equation (5)). Note that for a given good n, the estimated import elasticities are all negative, if the following condition holds:

$$a_{nn} \geq s_{nc}^t \left(1 - s_{nc}^t\right), \forall c, t.$$

Given that by construction $s_{nc}^t < 0$ for imports and $s_{nc}^t > 0$ for exports, the above is true if

$$a_{nn} \geq \bar{s}_n \left(1 - \bar{s}_n\right), \tag{20}$$

[7] Note that we do impose non-jointness in production. For a discussion of separability, see chapter 4 in Kohli (1991).

where $\bar{s}_n$ is the maximum (negative for imports, positive for exports) share in the sample for good n. Denote all the variables of such an observation (country) with an over-bar. We then difference Equation (19) with respect to this observation, where the curvature condition is most likely to be violated:

$$\begin{aligned} s_{nc}^t\left(\tilde{p}_{nc}^t, \tilde{p}_{-nc}^t, v_c^t\right) &= \tilde{a}_{0n} + \left(a_{0n}^t - \bar{a}_{0n}^t\right) + \left(a_{0nc} - \bar{a}_{0n}\right) + a_{nn}\left(\ln\frac{\tilde{p}_{nc}^t}{\tilde{p}_{-nc}^t} - \ln\frac{\bar{\tilde{p}}_n}{\bar{\tilde{p}}_{-n}}\right) \\ &\quad + \sum_{m=1, m\neq k}^{M} c_{nm}\left(\ln\frac{v_{mc}^t}{v_{kc}^t} - \ln\frac{\bar{v}_m}{\bar{v}_k}\right). \end{aligned} \tag{21}$$

Notice that differencing with respect to this observation does not affect the slope coefficients, a_{nn} and c_{nm}, while the estimated constant term, $\tilde{a}_{0n}$, now has the interpretation of $\bar{s}_n$, by construction. In addition, each country-year specific effect represents the differences in the average import or export share of country c at time t and $\bar{s}_n$.

To impose a non-negative constraint such as Equation (20) , we reparameterize Equation (21)as follows;[8]

$$a_{nn} = \tau_{nn}^2 + \tilde{a}_{0n}\left(1 - \tilde{a}_{0n}\right),$$

where $\tilde{a}_{0n}$ and τ are the parameters to be estimated nonlinearly. Thus, the final version of the share equation is:

$$\begin{aligned} s_{nc}^t\left(\tilde{p}_c^t, v_c^t\right) &= \tilde{a}_{0n} + \left(a_{0n}^t - \bar{a}_{0n}^t\right) + \left(a_{0nc} - \bar{a}_{0n}\right) + \left(\tau_{nn}^2 + \tilde{a}_{0n} - \tilde{a}_{0n}^2\right)\left(\ln\frac{\tilde{p}_{nc}^t}{\tilde{p}_{-nc}^t} - \ln\frac{\bar{\tilde{p}}_n}{\bar{\tilde{p}}_{-n}}\right) \\ &\quad + \sum_{m=1, m\neq k}^{M} c_{nm}\left(\ln\frac{v_{mc}^t}{v_{kc}^t} - \ln\frac{\bar{v}_m}{\bar{v}_k}\right) + u_{nc}^t, \end{aligned} \tag{22}$$

where a neoclassical regression error term, u_{nc}^t, is included to control for measurement error in the aggregate GDP deflator which is used to construct $\ln \tilde{p}_{-nc}^t$. Given that $\tilde{a}_{0n}$ and τ is nonlinear with respect to u_{nc}^t, nonlinear estimation techniques are necessary.

[8] Note that the imposition of the curvature conditions is binding in only 10 percent of the observations in our sample, but in order to ensure comparability in the estimation procedure we estimate all elasticities using the same methodology.

4 Data

The basic data consists of exports and imports data reported by different countries to the UN Comtrade system at the 6 digit of the Harmonized System (HS –around 4200 products). This data provides both value and volumes of exports and imports for each country allowing to calculate unit values. It is available at the World Bank through the World Integrated Trade System (WITS). The Harmonized System was introduced in 1988, but a wide use of this classification system only started in the mid 1990s. So the basic data will consist of an unbalanced panel of exports and imports for around 100 countries at the 6 digit level of the HS for the period 1988-2002. The number of countries will obviously vary from product to product depending on how many countries export or import the product and when different countries started reporting their trade statistics using the HS.

We use year dummies to control for the year specific effects. As for country specific effects, for the OECD countries in the sample, we employ country dummies, while the developing countries in the sample are aggregated into the 9 World Bank main geographic regions and regional dummies are used. This is to save some degree of freedom given the complicated nature of the nonlinear estimation. In addition, relative GDP per capita (relative to the GDP per capita of the observation where the curvature condition is more likely to be violated) is also introduced as additional country controls.

Data on GDP per capita, labor force, agriculture land, and the GDP deflator series are all from World Development Indicators (WDI, 2003). Data on capital endowments available in Feenstra and Kee (2004), which is constructed using perpetual inventory method based on real investment data in WDI (2003).

5 Empirical Results

We first discuss the results obtained for the estimation of import demand elasticities and then we turn to the estimates of export supply price elasticities.

5.1 Import Demand Elasticities

Given the lack of existing estimates on these good level elasticities, we need some guidelines from theory to judge our results:

1. The import demand for homogenous goods is more elastic than for heterogenous goods. Rauch (1999) classifies goods into these two categories, which we can use to test this hypothesis.

2. Import demand is more elastic at the disaggregate level – the substitution effect between cotton shirts and wool shirts is larger than the substitution effect between shirts and pants, or garment and electronics. Thus, we expect the HS 6 digit good level import demand elasticities estimates to be larger in magnitude (more negative) than HS 4 digit and HS 2 digit estimates. Broda and Weinstein (2004) uses a similar guideline for their elasticities of substitution estimates.

3. Import demand is more elastic in large countries. In large countries there is a larger range of domestically produced goods and therefore the sensitivity to import prices of import demand is expected to be larger. In other words, it is easier to substitute away from imports into domestically produced goods in large economies.

4. Import demand is less elastic in more developed countries. The relative demand for heterogenous goods is probably higher in rich countries. Given that heterogenous goods are less elastic, we expect the import demand to be less elastic in rich countries.

We will test our estimates against the above hypotheses. At HS 6 digit good level, we estimate a total of 363,777 import demand elasticities. The simple average across all countries and goods is -3.96 and the standard deviation is 7.88 suggesting quite a bit of variance in the estimates. Figure 1 shows the Kernel density estimate of the distribution of all estimated elasticities. The red line to the left denotes the sample mean (-3.96), and the line to the right is the sample median (-1.57).

All import demand elasticities are quite precisely estimated. The average t-statistics is around -14.4 which shows that our estimates are highly significant. The median t-statistics is around -2.7. Around 20 percent of the observations have t-statistics greater than -2, suggesting that the elasticities have not been very precisely estimated in those cases.

The estimates vary quite significantly across countries. The top three countries with the highest average elasticity across products are Japan, India and the United States with average import demand elasticities of -9.15, -7.71 and -7.43, respectively. The three countries with the lowest average import demand elasticities are Surinam, Maldives and Guyana with averages of -1.24, -1.54 and -1.60 respectively. Table 1 provides several moments of the estimated import demand elasticities by country: the simple average, the standard deviation, the median and the import-weighted average elasticity.

Figure 2 presents the Kernel density estimates of the distributions of import demand elasticities of Metal (HS 72-83) and Machinery (HS 84-89). Given that Metal products are expected to be more homogenous than Machinery, we see this as a first test into the homogeneity vs heterogeneity question (tests based on Rauch, 1999 will follow). The average import elasticity of Metal is -1.70 while it is –1.58 for Machinery. A simple mean test supported the hypothesis that Metal import demand is more elastic than that of the Machinery, with a t-statistics of -4.33. Thus we found support that homogenous goods tend to be more elastic than heterogenous goods.

Figures 3 and 4 jointly test the last two hypotheses that import demand is more elastic in large and less developed countries, by regressing the median import elasticities on log of GDP and log of GDP per capita. It is clear that both hypotheses cannot be rejected.

Finally, we estimated import demand elasticities, but aggregating our data at the 4 and 2 digit level of the Harmonized System, as well as at the aggregate level. Table 3 illustrates the average elasticities obtained at different levels of aggregation. Note that in principle the aggregated import demand elasticities should be equal to the import-weighted averages. We therefore also calculated the aggregate elasticities using import-weights at the 4 and 2 digit. We correlated the calculated and estimated series and obtained the following correlation coefficients XX, YY, ZZ.

5.2 Export supply price elasticities

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6 Concluding Remarks

This paper provides a methodology to estimate import demand and export supply price elasticities for a wide variety of countries at the six digit level of the Harmonized System (more than 4200 tariff lines), that can be implemented with existing trade data.

Sample average of the estimated import demand elasticities at HS 6 digit is about -4, while the sample median is about -1.6. Our estimates exhibit some interesting patterns. First, we found that the import demand elasticities are larger for homogenous goods. Second, the average estimated elasticities decrease as we increase the level of aggregation at which we estimate them. Third, large countries tend to have more elastic import demands. Fourth, more developed countries tend to have less elastic import demand. To conclude, the estimated import demand elasticities exhibit significant variation across countries and products.

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The estimated elasticities and their standard errors are provided in a companion STATA file.

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References

[1] Anderson, James and Peter Neary (2003), "The Mercantilist index of trade policy", *International Economic Review* 44(2), 627-649.

[2] Athukorola, P. and J. Riedel (1994), "Demand and supply factors in the determination of NIE exports: a simultaneous error-correction model for Hong Kong: a comment," *Economic Journal* 105, 1411-1414.

[3] Blonigen, Bruce and Wesley Wilson (1999), "Explaining Armington: What determines substitutability between home and foreign goods", *Canadian Journal of Economics* 32(1), 1-21.

[4] Broda, Christian and David Weinstein (2003), "Globalization and the gains from variety", mimeo.

[5] Caves, Douglas W., Laurits R. Christensen, and Erwin Diewert (1982), "Multilateral Comparisons of Output, Input, and Productivity using Superlative Index Numbers," *Economic Journal* 92, 73-86.

[6] Feenstra, Robert (1995), "Estimating the effects of trade policy", in Gene Grossman and Kenneth Rogoff, eds., *Handbook of International Economics*, vol. 3, Elsevier, Amsterdam.

[7] Feenstra, Robert and Hiau Looi Kee (2004), "Product Variety and Country Productivity," University of California, Davis and the World Bank.

[8] Gallaway, Michael, Christine McDaniel and Sandra Rivera (2003), "Short-run and long-run industry-level estimates of US Armington elasticities", *North American Journal of Economics and Finance* 14, 49-68.

[9] Harrigan, James (1997), "Technology, Factor Supplies, and International Specialization: Estimating the Neoclassical Model," *The American Economic Review* 87 (4), 475-494.

[10] Kee, Hiau Looi, Alessandro Nicita and Marcelo Olarreaga (2004), "Estimating Multilateral Trade Restrictiveness Indices", mimeo, The World Bank.

[11] Kohli, Ulrich (1991), *Technology, Duality, and Foreign Trade: The GNP Function Approach to Modeling Imports and Exports,* The University of Michigan Press, Ann Arbor.

[12] Leamer, Edward (1974), "National tariff averages with estimated weights", *Southern Economic Journal* 41(1), 34-46.

[13] Marquez, Jaime (1999), "Long-period stable trade elasticities for Canada, Japan, and the United States", *Review of International Economics* 7, 102-116.

[14] Marquez, Jaime (2002), *Estimating trade elasticities*, Kluwer, Boston.

[15] Marquez, Jaime (2003), "US imports", mimeo, presented at the AEA meetings in January 2004.

[16] Panagariya, Arvind, Shekhar Shah and Deepak Mishra (2001), "Demand elasticities in international trade: are they really low?" *Journal of Development Economics* 64, 313-342.

[17] Rauch, James (1999), "Network versus markets in international trade", *Journal of International Economics* 48, 7-35.

[18] Riedel, J. (1988), "The demand for LDC exports of manufactures: estimates for Hong Kong," *Economic Journal* 98, 138-148.

[19] Schott, Peter (forthcoming), "Across-Product versus Within-Product Specialization in International Trade," *Quarterly Journal of Economics*.

[20] Shiells, Clinton, Robert Stern and Alan Deardorff (1987), "Estimates of the elasticities of substitution between imports and home goods for the United States," *Weltwirtschtarchives*, 122, 497-519.

[21] Shiells, Clinton, David Roland-Holst and Kenneth Reinert (1993), "Modeling a North American Free Trade Area: Estimation of flexible functional forms", *Welwirtschaftliches Archiv* 129, 55-77.

[22] Stern et al (1976), *Price elasticities in international trade : an annotated bibliography*, London.

[23] Winters, Alan (1984), "Separability and the specification of foreign trade functions," *Journal of International Economics* 17, 239-263.

[24] Kei-Mu Yi (2003), "Can vertical specialization explain the growth of world trade?", *Journal of Political Economy* 111, 52-102.

Figure 1: Distribution of HS 6-Digit Import Demand Elastities

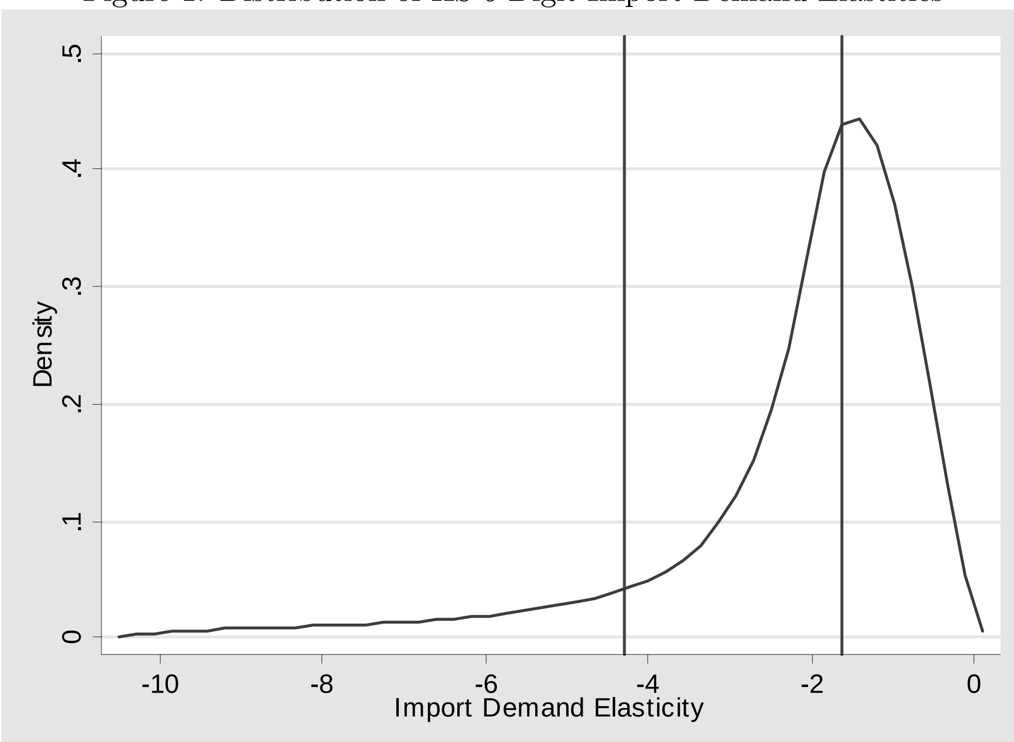

Figure 2: Distribution of Import Demand Elastities: Metal vs. Machinery

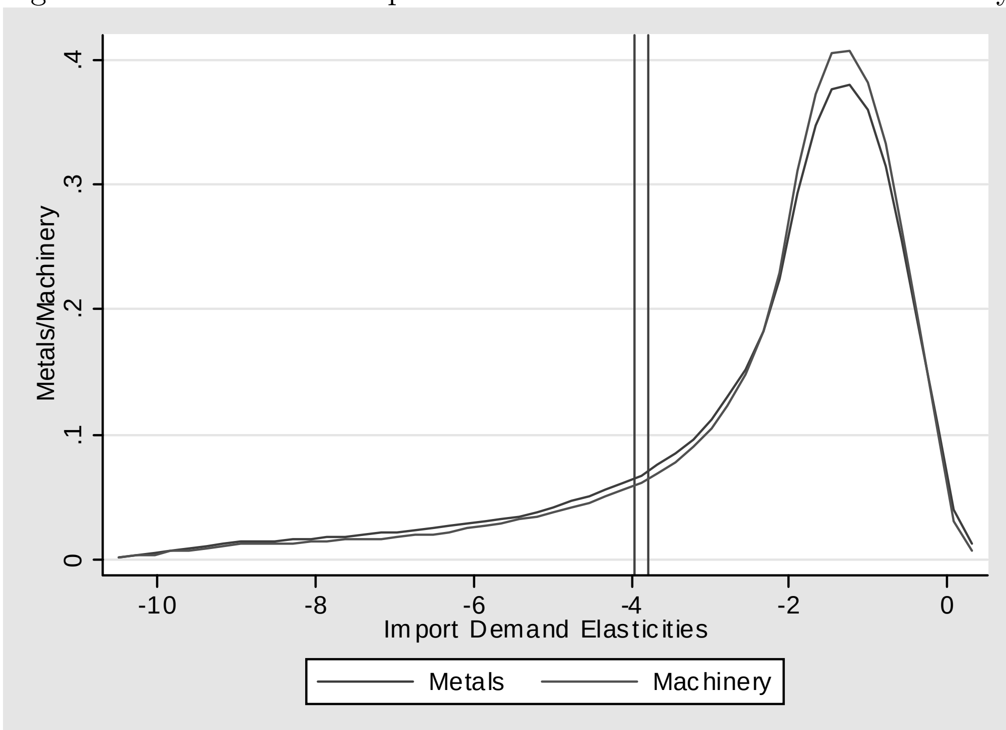

Figure 3: Import Demand Elastities vs Log of GDP

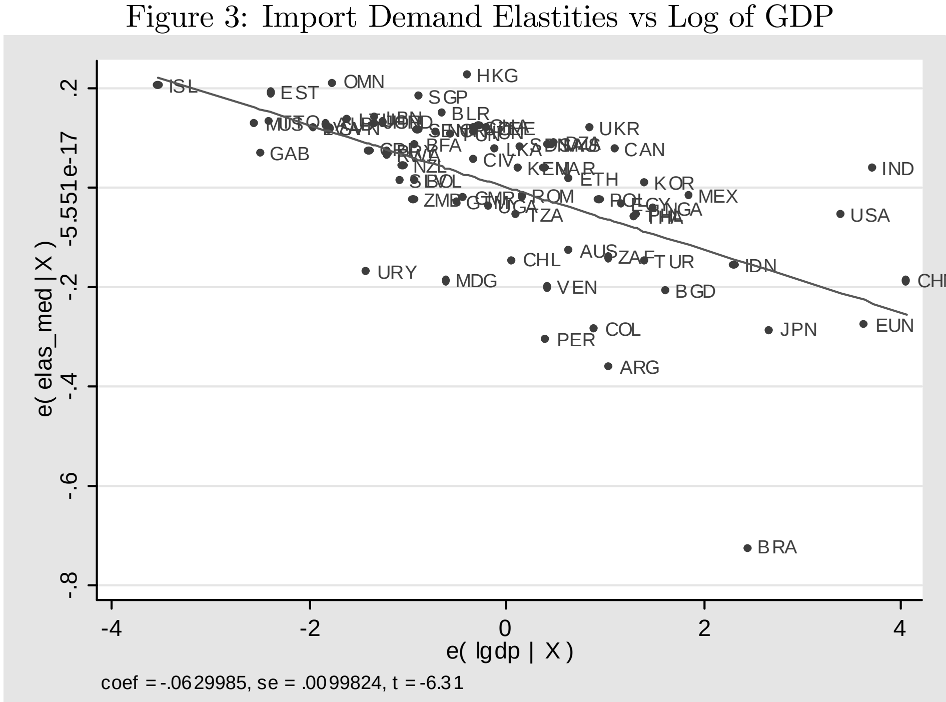

Figure 4: Import Demand Elastities vs Log of GDP per Capita

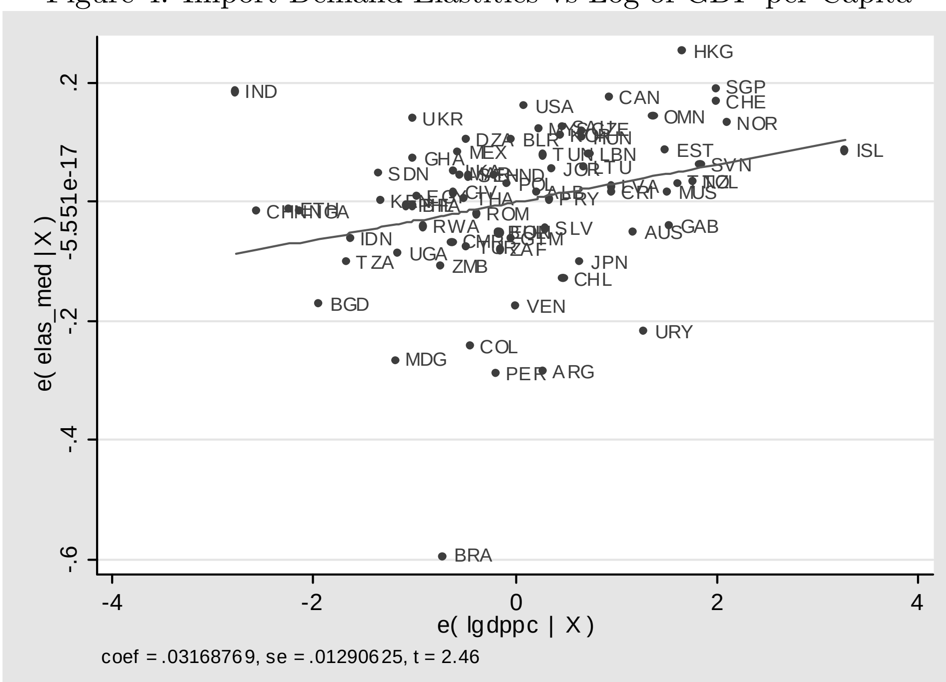

Figure 5: Estimated elasticities: sample moments

Country	Simple Average	Standard Deviation	Median	Import-weighted Average	Country	Simple Average	Standard Deviation	Median	Import-weighted Average	Country	Simple Average	Standard Deviation	Median	Import-weighted Average
ARE	-3.84	7.51	-1.55	-1.59	FRA	-4.18	7.93	-1.75	-2.31	MWI	-2.52	4.44	-1.34	-1.39
ARG	-6.31	11.57	-2.47	-3.41	GAB	-4.02	7.5	-1.82	-1.8	MYS	-3.19	7.02	-1.34	-1.36
ARM	-3.01	4.88	-1.47	-1.34	GBR	-4.02	7.77	-1.77	-2.08	NER	-3.79	6.64	-1.74	-1.71
AUS	-5.23	9.82	-2.06	-2.73	GEO	-3.98	6.03	-1.98	-1.77	NGA	-5.16	9.5	-1.99	-1.96
AUT	-3.47	6.76	-1.49	-1.8	GHA	-3.69	7.2	-1.56	-1.49	NIC	-2.31	4.36	-1.29	-1.33
AZE	-4.19	7.51	-1.66	-1.81	GIN	-4.53	8.49	-1.88	-1.85	NLD	-3.37	6.94	-1.44	-1.67
BDI	-2.31	3.15	-1.33	-1.56	GMB	-1.77	2.47	-1.17	-1.22	NOR	-4.48	8.94	-1.72	-2.04
BEL	-2.74	6	-1.29	-1.46	GRC	-3.82	7.44	-1.75	-2.07	NZL	-4.16	8.17	-1.72	-2.02
BEN	-4.04	7.5	-1.68	-1.54	GTM	-4.54	9.08	-1.81	-1.85	OMN	-4.32	8.76	-1.48	-1.35
BFA	-3.5	6.41	-1.59	-1.59	GUY	-1.6	3.43	-1.09	-1.16	PAN	-3.83	7.39	-1.57	-1.77
BGD	-6.01	10.65	-2.23	-2.04	HKG	-2.89	6.47	-1.21	-1.19	PER	-5.21	9.46	-2.17	-2.38
BGR	-3.32	6.41	-1.48	-1.63	HND	-2.89	5.53	-1.39	-1.41	PHL	-4.02	7.66	-1.7	-1.59
BLR	-3.22	6.49	-1.33	-1.42	HRV	-2.91	5.86	-1.4	-1.65	POL	-3.45	7.18	-1.52	-1.83
BLZ	-1.69	2.08	-1.2	-1.24	HUN	-2.76	5.26	-1.37	-1.49	PRT	-3.17	6.49	-1.51	-1.77
BOL	-4.09	7.44	-1.83	-1.86	IDN	-4.76	9.18	-1.75	-2.11	PRY	-3.99	7.29	-1.67	-1.73
BRA	-7.27	12.18	-2.82	-4.11	IND	-7.71	12.81	-2.92	-3.67	ROM	-3.27	6.07	-1.57	-1.76
BRB	-2.65	5.58	-1.32	-1.52	IRL	-3.44	7.08	-1.46	-1.6	RWA	-3.82	6.35	-1.68	-1.97
CAF	-2.72	3.5	-1.47	-1.61	IRN	-5.28	10.13	-2.04	-1.98	SAU	-4.53	8.54	-1.78	-1.97
CAN	-4.47	8.8	-1.76	-2.02	ISL	-3.9	7.87	-1.54	-1.79	SDN	-5.92	10.69	-2.09	-1.86
CHE	-3.97	8.55	-1.52	-1.89	ISR	-2.11	1.65	-1.51	-1.46	SEN	-3.52	6.18	-1.63	-1.55
CHL	-4.15	8.35	-1.7	-1.99	ITA	-4.33	7.83	-1.91	-2.38	SGP	-2.49	5.75	-1.21	-1.2
CHN	-5.04	9.3	-1.91	-2.43	JAM	-3.27	6.78	-1.43	-1.41	SLV	-4.19	8.39	-1.68	-1.81
CIV	-5.3	9.28	-2.09	-1.87	JOR	-3.23	6.65	-1.44	-1.4	SUR	-1.24	0.76	-1.04	-1.06
CMR	-5.65	9.59	-2.33	-2.2	JPN	-9.15	14.7	-3.38	-4.14	SVK	-2.69	5.14	-1.32	-1.46
COG	-3.23	5.59	-1.5	-1.51	KEN	-4.46	8.31	-1.79	-1.73	SVN	-2.78	5.7	-1.29	-1.48
COL	-5.01	9.11	-2.02	-2.49	KOR	-4.41	8.17	-1.68	-2.05	SWE	-4.09	8.37	-1.62	-1.95
COM	-1.86	2.38	-1.23	-1.27	LBN	-3.94	7.92	-1.57	-1.54	TGO	-2.83	5.1	-1.46	-1.43
CRI	-3.61	7.06	-1.55	-1.63	LKA	-4.12	8.34	-1.54	-1.55	THA	-4.09	8.78	-1.52	-1.7
CYP	-3.19	6.29	-1.44	-1.54	LTU	-3.3	6.78	-1.44	-1.52	TTO	-3.36	7.42	-1.45	-1.57
CZE	-2.65	5.27	-1.3	-1.47	LVA	-3.05	6.63	-1.4	-1.54	TUN	-3.39	7.14	-1.44	-1.5
DEU	-4.17	7.82	-1.82	-2.2	MAR	-4.24	8.33	-1.7	-1.87	TUR	-4.4	8.34	-1.84	-2.3
DNK	-3.95	8.2	-1.63	-1.93	MDG	-3.77	6.7	-1.85	-2.28	TZA	-4.72	8.91	-1.9	-2.03
DZA	-4.75	8.41	-1.94	-1.95	MDV	-1.54	2.17	-1.13	-1.18	UGA	-5.17	9.32	-2	-2.14
EGY	-5.15	9.48	-1.96	-2.05	MEX	-4.02	7.93	-1.72	-2.05	UKR	-4.64	8.86	-1.81	-1.7
ESP	-4.02	7.61	-1.82	-2.33	MKD	-2.79	5.32	-1.44	-1.56	URY	-4.84	9.2	-1.96	-2.21
EST	-2.22	4.51	-1.2	-1.27	MLI	-4.17	7.88	-1.67	-1.48	USA	-7.44	12.38	-2.8	-3.33
ETH	-3.94	7.07	-1.69	-1.79	MLT	-2.51	5.14	-1.29	-1.35	VEN	-5.07	9.47	-2.08	-2.51
FIN	-4.09	7.85	-1.71	-2.13	MNG	-2.13	3.56	-1.22	-1.26	ZAF	-4.85	9.38	-1.87	-2.37
					MUS	-2.85	5.91	-1.38	-1.43	ZMB	-3.1	5.06	-1.56	-1.62