# Import Demand Estimation and the Generalized Composite Commodity Theorem

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## Abstract

A frequently encountered problem in import demand estimation is how to account for competition between imports and domestic production. Traditionally, use of the Armington model has been a way to handle this problem. This is a disaggregate model which distinguishes commodities by country of origin with import demand determined in a separable two-step procedure. The model appears frequently in analysis of international agricultural markets. However, the Armington model relies on a set of weak separability assumptions, which several authors have shown to be highly questionable. In this paper, a new aggregation theorem, the Generalized Composite Commodity Theorem (GCCT), is applied to test whether imports can be treated as a separate group. An advantage with the GCCT is that only import data is required to conduct the test. The application is to the imports of swordfish to the U.S. with implications for U.S. and international swordfish management policies.

**Keywords:** Armington, separability, GCCT, demand system, sword fish.

JEL Classification: F18, Q11, Q22

## Introduction

Demand systems have been used in a number of papers when investigating trade allocations with Duffy *et al* and Davis and Kruse as some recent examples. These papers are based on the Armington approach, and utilize the assumptions that all goods from all sources are separable from each other as well as all other goods to limit the data requirements. These assumptions allow the goods in question to be regarded as a separate group that can be treated as an aggregate good in relation to all other goods. These separability assumptions are not in general necessary between imports from different countries, as flexible functional form like Deaton and Muellbauer's (1980) AIDS allows import demand equations where the imported goods are not separable (Winters, Alston *et al*,). However, data on consumption of the good produced domestically are often not available. Moreover, as forcefully argued by Winters, the assumption of separability between domestic and imported products are likely to be unreasonable, and if so, will lead to biased elasticity estimates. Winters tested the hypothesis with UK trade data and rejected the assumption.

In this paper we will use a different approach, the Generalized Composite Commodity Theorem (GCCT) of Lewbel, to justify aggregation, and therefore the estimation of a demand system of only import demand equations. The main advantage with this approach is that to test whether this theorem holds for a group of goods, one only needs the data that is used when one is estimating a demand system. The GCCT can accordingly be used to easily validate that one can treat the goods in question as a separate group provided that the theorem holds, and without use of additional data that often is not available. Hence, one can use only import data to investigate whether import demand functions can be estimated without taking account of demand for domestic production of the same good. The GCCT has been found useful as an aggregation criterion in several recent studies, including Asche, Bremnes and Wessells, Davis, Lin and Shumway and Reed, Levedahl and Hallahan. Our study is most closely related to Reed, Levedahl and Hallahan, although where they are interested in finding consistent aggregates to estimate aggregated food demand, we are interested in finding a consistent aggregate, to investigate the demand within the group of goods the aggregate encompasses.

Several studies have shown that it is reasonable to treat the set of prices used in demand analyses as nonstationary data series. This includes market delineation studies (Goodwin and Schroeder, Doane and Spulber, Asche, Bremnes and Wessells), aggregation studies (Lewbel, Davis, Lin and Shumway) and demand studies (Chambers, Attfield, Karagiannis and Mergos, Reed, Levedahl and Hallahan). This makes it straightforward to use cointegration tests when testing for the GCCT, but provide some extra challenges when estimating the demand system as one need to take the nonstationary nature of the data into account. We will follow the approaches of Asche, Salvanes and Steen and Karagiannis and Mergos in modeling the demand equations in an error correction framework, but we will restrict the dynamics to be autoregressive.

The empirical application will estimate import demand for swordfish to US. This is an interesting fish species in an import demand context, because there have been several campaigns in the US to limit swordfish imports because of environmentally negative fishing practices. This includes the "Give swordfish a break" campaign targeting US chefs in 1998-2000. The impact of such concerns on the import from different countries will depend on the characteristics of the demand equation. We will here estimate demand equations for swordfish from Brazil, Chile, the Caribbean, other north and other south using monthly US import data for the period 1989 to 2004.

## Import Demand and Aggregation

Aggregation theory seeks to answer the question: Under what conditions will there exist meaningful economic aggregates? This is necessary to justify analysis of only a limited group of goods like import demand of a product from different sources. There are two fundamentally different approaches to validate aggregation – different forms of separability and relationships between prices (Deaton and Muellbauer, 1980a). Creating groups of goods that are investigated in isolation from the rest of the consumer's bundle is normally justified with a weak separability assumption. Weak separability gives conditions for the structure of consumers' preferences so that it is valid to investigate the demand for a limited number of goods. However, whether a weak separability assumption is valid depends on the relationship between the goods in question and all other goods in the consumer's bundle. To test weak separability one needs data on all goods, and it involves estimation of a much larger demand system. Tests are in general difficult to conduct and have low power (Lewbel). This leads most researchers to assume weak separability without any testing. However, this also makes the results questionable since one can raise doubts with respect to the validity of the separability assumption, as for example, Winters.

Aggregation based on relationships between prices is formulated in the Composite Commodity Theorem,CCT (Hicks,; Leontief). The CCT basically states that a group of goods with proportional prices can be aggregated and be represented as a single good with a single price. However, the CCT must hold as an identity. The GCCT of Lewbel is hence a generalization that gives an empirically operational version of the CCT. Furthermore, Lewbel shows that an AIDS aggregates consistently within each group.

The GCCT can be represented as follows. Define $\rho_i$ as the ratio of the price of good $i$ to the price index of the group of interest, $P_I$.

$$\rho_i = p_i / P_I \qquad (1)$$

If the distribution of the relative price $\rho_i$ is independent of the group index $P_I$, the GCCT will hold. Let $r_i = \ln \rho_i$ and $R_I = \log P_I$. Lewbel shows that for nonstationary prices, this is equivalent to finding that $u_t$ in the relationship

$$r_i - R_I = u_t \tag{2}$$

is nonstationary, or that the relative price $\rho_i$ is not cointegrated with $P_I$.[1]

When testing whether a group of goods can be aggregated with the GCCT, one needs only price and quantity data for the goods of interest (the quantity data is necessary to construct the price index). Hence, in contrast to weak separability, the GCCT can be easily be used to verify that the group of goods considered is a valid group using only the data required to estimate the demand system of interest. If this condition fails, there may of course be other criteria that provide support for the group. However, if these are not testable, they provide much poorer support for investigating the group of interest separate from other goods.

## AIDS estimation

We will use the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980b), as this seems to be the most popular demand system in empirical work. The equation for import from the *i*th country's expenditure share, $w_i$, is given by

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i (\ln x - \ln P), \tag{3}$$

where $\ln P^s$ is a price index defined by

$$\ln P = \alpha_0 + \sum_{k=1}^{n} \alpha_k \ln p_k + \frac{1}{2}\sum_{k=1}^{n}\sum_{j=1}^{n} \gamma_{kj} \ln p_k \ln p_j \tag{4}$$

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[1] Most common functional forms for demand systems, including the AIDS, will aggregate consistently under the GCCT.

In equations (3) and (4), $p_j$ denotes the per unit price of good from country $j$ and $x$ is the total expenditure on all import included in the system. Restrictions for homogeneity ($\Sigma_j \gamma_{ij} = 0\ \forall i,$) and symmetry ($\gamma_{ij} = \gamma_{ji}\ \forall i,j,$) are imposed.

The AIDS is linear except for the translog price index ln$P$. This problem has traditionally been circumvented in most applied work as suggested by Deaton and Muellbauer, by using a scaled Stone's price index, $AP_t^*$, where $A$ is a constant scaling factor and $\ln P_t^* = \sum_i w_{it} \ln p_{it}$ , which makes the system linear. Deaton and Muellbauer argue that if prices are highly collinear, Stone's index should be a good approximation of the translog index.

The use of Stone's price index has been questioned by several authors (Chalfant, Green and Alston, Pashardes, Buse, Moschini). There are several explanations for this, including simultaneity bias (measurement errors), omitted variables and that Stone's index is not invariant to units of measurement. To avoid these problems, Moschini suggested three alternative Stone indices that correspond to loglinear versions of the classical Laspeyre, Paasche and Tornquist indices. We will use the loglinear analogue to a Laspeyre index, which can be written as

$$\ln P_t^L = \sum_{i=1}^{n} w_i^0 \ln p_{it} \tag{5}$$

Each $w_i^0$ is the budget share at some fixed point, and constant. This index has the additional advantage that it cannot be endogenous due to variation in the expenditure shares within the index. Moreover, Buse and Chan indicate that this is the best performing of the linear indicies in Monte Carlo experiments.

## Empirical Analysis

We will here investigate US import demand for swordfish. Substitution between suppliers of swordfish is an interesting product, since different producers at different times are targeted in boycott campaigns due to the dolphin safety issue. The United States is the world's largest swordfish market, consuming approximately twenty-five percent of world landings (Crowder and Myers). In 2004, the U.S. imported a total of 6,500mt of fresh swordfish valued at $45 million from 28 countries (NMFS). Roughly 70% of U.S. swordfish imports are imported fresh. Chile, Brazil, Australia, Canada, Mexico, and South Africa were the major sources of fresh swordfish. An increasing amount of swordfish is imported from Caribbean Sea island nations such as Barbados, Trinidad and Tobago, Antigua, Grenada, and the British Virgin Islands. These nations have begun to promote fisheries development in their region.

Our data on swordfish import to the US were obtained from the National Marine Fisheries Service (www.nmfs.noaa.gov). Monthly prices and quantities on swordfish import from all countries that had sold swordfish to US during the period January 1989 to December 2004 was utilized in the study. The data was divided in five groups based on geography and sold quantity. We used the following groups, Chile, Brazil, Caribbean, and two residual groups denoted other north, ON and other south, OS. Some descriptive statistics of the data are presented in table 1, and a figure visualizing price development and a figure with market shares are presented in figure 1 and 2.

To test for the GCCT, we test for cointegration between the relative prices of the different countries and the price index. The first step is then to investigate the time series properties of the data. In table 1, Augmented Dickey-Fuller (ADF) tests are reported.[2] As shown, all prices and the price index are nonstationary in levels while all relative prices seem to be stationary. Accordingly, they cannot be cointegrated with the price index. Hence, we must conclude that the GCCT holds for this group of goods, and we can justify looking at swordfish imported to the USA separately from domestic produced salmon. We can accordingly proceed by estimating an import demand system for this group of goods.

However, before we can estimate AIDS demand system, we have to investigate the time series properties also of the shares and the real expenditure variable. As shown in table 1 are non stationary in their levels. There are a number of approaches in the literature to handle nonstationarity in demand systems. All have in common that one must confirm that each demand equation indeed is a long run demand relationship. This is done by showing that the demand equations are cointegrated.

The demand system was estimated with monthly dummies, and autocorrelation was corrected for by the Bernt and Savin approach discussed in Rickertsen, Kristofersson and Lothe. A Johansen test on the budget share equations confirms that the estimated equations are long-run relationships, as reported in Table 3.  The estimated parameters are reported in Table 4 and the compensated and uncompensated price and expenditure elasticities are reported in Tables 5 and 6.

As expected the own-price elacticities are negative. All uncompensated elasticities are inelastic and significantly different from zero, as are the compensated elasticities with the

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[2] The tests are reported with six lags. However, the results are, with a few exceptions, insensitive to the choice of lag length. For the exceptions, the deviations are on few lags, and when lag coefficients are statistically significant at higher lags.

exception of other south. For the uncompensated elasticities, the numerical values are relatively equal for each of the groups. That demand is so inelastic is an indication that there are few substitution possibilities for the different fresh swordfish sources. Hence, measures that reduce demand can potentially be efficient in improving fishing practices

The expenditure elasticities are positive and significantly different from zero. The demand for swordfish from Chile and Other south is more expenditure elastic than is the demand for swordfish from the other countries. The expenditure elasticity for swordfish from Caribbean is low. This may not be too surprising in the present context since the Caribbean with their close proximity to the US is likely to find the US market the most profitable under any circumstance, as transportation costs prevents the product to be shipped elsewhere.

It is somewhat surprising with the relatively large number of goods that are found to be complements from the compensated elasticities. This is then of course also true for the uncompensated elasticities since the expenditure effect will amply this for normal goods. Moreover, there are no clear groups of species that are complementary, so the elasticities do not allow us to make any conclusions with respect to groups within the system. Although it is difficult to interpret these results, they seems to indicate that there is a tendency that increased demand for fresh swordfish leads to increased demand from all sources. If so, any measures that reduce demand has potential to be efficient in targeting negative fishing practices.

## Concluding remarks

The assumption that the imports of a good is separable from all other goods including domestic production of the same good has always been questionable when investigating import demand (Winters). In this paper we show that one can investigate whether the import demand equations can be analyzed as a separate group using the Generalized Composite Commodity Theorem (GCCT) of Lewbel. The main advantage with this approach is that to test whether this theorem holds for a group of goods, one only needs the data that is used when one is estimating a demand system. Hence, one can use only import data to investigate whether import demand functions can be estimated without taking account of demand for domestic production of the same good.

As an empirical application we estimated the import demand for fresh swordfish to the US from five countries or groups of countries. Swordfish is an interesting product to investigate the import structure for, as there have been several initiatives in the US to reduce imports because of poor environmental practices in many swordfish fisheries. We found that the GCCT held in our data, and accordingly we could proceed by estimating a demand system for this group of products. Demand was found to be inelastic for all product, indicating a limited degree of substitution possibilities. Hence, measures that reduce demand are potentially effective in changing fishermen practices.

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## Table and figures

### Table 1. Dickey-Fuller tests, GCCT

| Variable | Test statistics |
|---|---|
| Other south vs. Index | -0.248 (13) |
| Other north vs. Index | -0.343 (13) |
| Caribbean vs. Index | 0.464 (13) |
| Chile vs. Index | -0.788 (13) |
| Brazil vs. Index | -0.516 (13) |
| Relative OS vs index | -1.491 (13) |
| Relative ON vs index | -1.175 (13) |
| Relative Caribbean vs index | -1.277 (13) |
| Relative Chile vs index | -1.700 (13) |
| Relative Brazil vs index | -1.697 (13) |

* indicates significant at a 5% level. Critical value at a 5% level is -2.882.

**Table 2. Dickey Fuller tests, demand system data**

| Variable | Test statistics, levels |
|---|---|
| Price 1 | -0.3857 (13) |
| Price 2 | -2.287 (13) |
| Price 3 | -0.617 (13) |
| Price 4 | -2.186 (13) |
| Price 5 | -2.709 (13) |
| Share 1 | -1.111 (13) |
| Share 1 | -1.341 (13) |
| Share 1 | -1.755 (13) |
| Share 1 | -1.253 (13) |
| Share 1 | -1.201 (13) |
| Expenditure | |

* indicates significant at 5% level. Critical value at 5% level is -2.882

**Table 3. Johansen cointegration test on the share equations**

| $H_0$:Rank=p | **Max** | | **Trace** | |
|---|---|---|---|---|
| | Test statistic | Critical value at a 5% level | Test statistic | Critical value at a 5% level |
| p==0 | 79.6* | 14.1 | 152.6* | 15.4 |
| p<=1 | 72.97* | 3.8 | 72.97* | 3.8 |

* indicates significant at a 5% level and ** indicates significant at a 10% level.

## Table 4. Parameter estimates

| | $\alpha_{i0}^{s}$ | $\gamma_{ij}^{s}$ | | | | | $\beta_i$ | $\theta_{im}$ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | | 1 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Other south | 0.287 | 0.131 | -0.040 | 0.026 | -0.140 | 0.023 | 0.072 | 0.026 | 0.033 | -0.035 | -0.102 | -0.162 | -0.135 | -0.141 | -0.172 | -0.118 | -0.072 | 0.002 |
| | (13.33) | (5.79) | (-2.38) | (1.21) | (-6.23) | (2.48) | (4.45) | (0.86) | (1.17) | (-1.25) | (-3.63) | (-5.40) | (-4.50) | (-4.45) | (-5.34) | (-3.98) | (-2.50) | (0.08) |
| Other north | 0.071 | | 0.070 | -0.055 | 0.053 | -0.029 | 0.014 | 0.025 | 0.006 | -0.028 | -0.027 | -0.032 | 0.005 | 0.194 | 0.370 | 0.406 | 0.318 | 0.039 |
| | (2.42) | | (2.71) | (-3.15) | (2.23) | (-4.23) | (0.63) | (0.58) | (0.14) | (-0.74) | (-0.71) | (-0.79) | (0.12) | (4.53) | (8.40) | (10.04) | (8.10) | (1.08) |
| Caribbean | 0.393 | | | 0.099 | -0.068 | -0.002 | -0.149 | 0.019 | -0.006 | -0.081 | -0.160 | -0.177 | -0.188 | -0.194 | -0.196 | -0.210 | -0.167 | -0.063 |
| | (18.82) | | | (3.02) | (-2.68) | (-0.15) | (-9.43) | (0.64) | (-0.20) | (-3.00) | (-5.78) | (-6.03) | (-6.42) | (-6.34) | (-6.25) | (-7.30) | (-5.97) | (-2.46) |
| Chile | 0.195 | | | | 0.172 | -0.018 | 0.074 | -0.060 | -0.059 | 0.118 | 0.296 | 0.377 | 0.323 | 0.137 | -0.006 | -0.085 | -0.089 | 0.001 |
| | (6.31) | | | | (4.27) | (-1.76) | (3.21) | (-1.32) | (-1.44) | (2.93) | (7.20) | (8.70) | (7.48) | (3.05) | (-0.13) | (-1.98) | (-2.14) | (0.02) |
| Brazil | 0.054 | | | | | 0.026 | -0.010 | | | | | | | | | | | |
| | (7.05) | | | | | (2.11) | (-1.81) | | | | | | | | | | | |

**Table 5. Compensated price elasticities calculated at mean values (t-values in parentheses)**

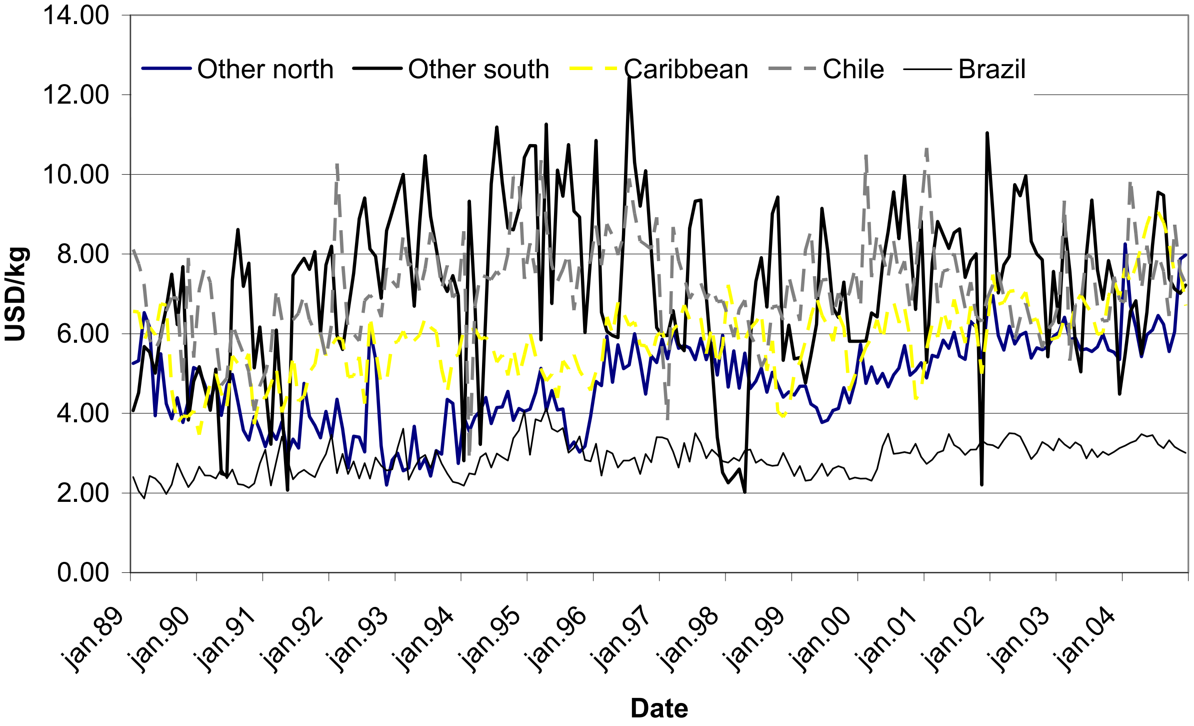
| | Other south | Other north | Caribbean | Chile | Brazil |
|---|---|---|---|---|---|
| Other south | -0,150 | -0,026 | 0,420* | -0,417* | 0,174* |
| | -(1,337) | -(0,317) | (4,018) | -(3,777) | (3,872) |
| Other north | -0,031 | -0,417* | -0,027 | 0,582* | -0,107* |
| | -(0,317) | -(2,739) | -(0,268) | (4,172) | -(2,670) |
| Caribbean | 0,290* | -0,016 | -0,370* | 0,040 | 0,057 |
| | (4,018) | -(0,268) | -(3,323) | (0,463) | (1,421) |
| Chile | -0,312* | 0,365* | 0,043 | -0,094 | -0,003 |
| | -(3,777) | (4,172) | (0,463) | -(0,628) | -(0,070) |
| Brazil | 0,564* | -0,291* | 0,266 | -0,011 | -0,528* |
| | (3,872) | -(2,670) | (1,421) | -(0,070) | -(2,726) |

Note: An asterisk indicates the elasticity is significant at the 5% level

**Table 6:** Uncompensated price and expenditure elasticities calculated at mean values (t-values in parentheses)

| | Other south | Other north | Caribbean | Chile | Brazil | Expenditure |
|---|---|---|---|---|---|---|
| Other south | -0.425* | -0.257* | 0.021 | -0.786* | 0.089 | 1.357* |
| | (-3.60) | (-3.28) | (0.19) | (-7.21) | (1.94) | (16.91) |
| Other north | -0.250* | -0.601* | -0.345* | 0.289* | -0.174* | 1.081* |
| | (-2.30) | (-4.13) | (-3.00) | (1.99) | (-4.16) | (8.37) |
| Caribbean | 0.190* | -0.099 | -0.515* | -0.093 | 0.026 | 0.491* |
| | (2.54) | (-1.76) | (-4.47) | (-1.10) | (0.64) | (9.11) |
| Chile | -0.570* | 0.149 | -0.330* | -0.439* | -0.082* | 1.272* |
| | (-6.44) | (1.75) | (-3.29) | (-2.96) | (-2.16) | (15.01) |
| Brazil | 0.395* | -0.432* | 0.021 | -0.237 | -0.580* | 0.833* |
| | (2.62) | (-4.15) | (0.11) | (-1.50) | (-2.98) | (9.05) |

Note: An asterisk indicates the elasticity is significant at the 5% level.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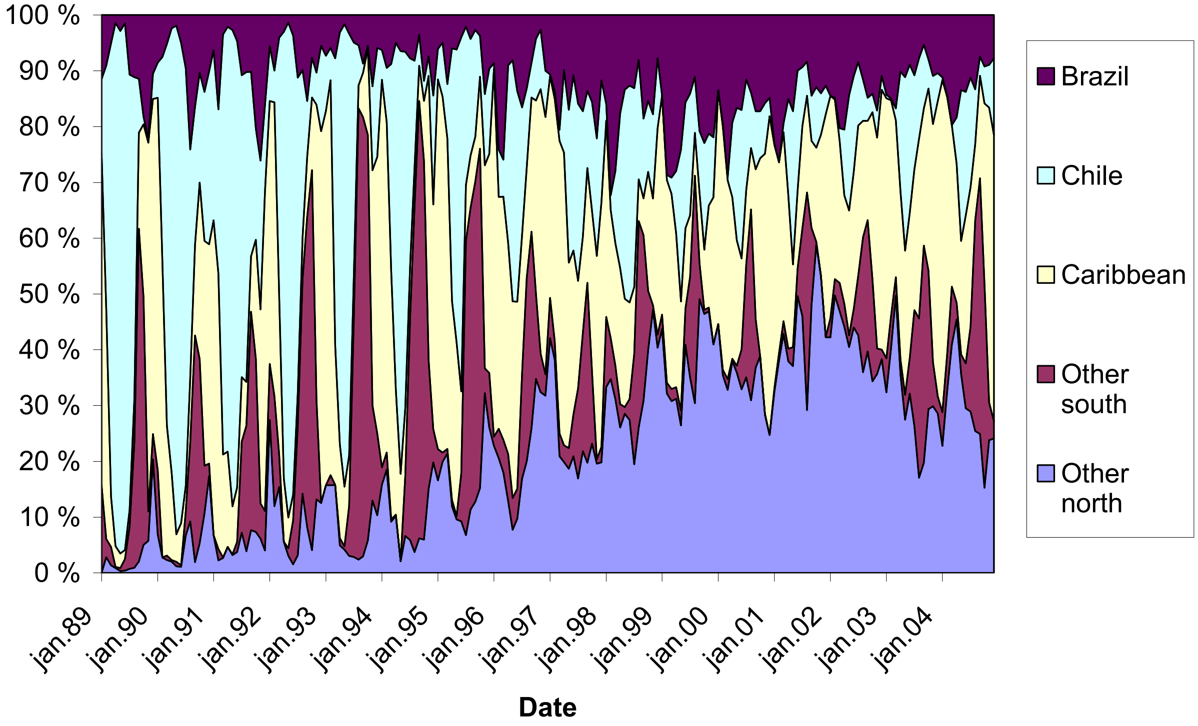
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