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SFB 649 Discussion Paper 2007-018

# Simultaneous Causality in International Trade

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# Simultaneous Causality in International Trade<sup>1</sup>

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## Abstract

This paper proposes estimating causalities in bilateral international trade in simultaneous systems, including domestic and foreign GDP as well as mutual trade flows. Conventional macroeconomic theory mainly follows partial approaches like import functions or export-led growth. Focusing on the US relations with Euroland and Canada, cointegration analyses however reveal, that the system dynamics, and so both im- and exports, are simply governed by US GDP shocks. In conclusion, exploring sources and effects of international trade should be seen as an inherently empirical task.

*Keywords:* Import, Export, Causality, Cointegration

*JEL classification:* F10, C32

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# 1 Economic Introduction

Empirical analyses exploring origins and effects of trade flows normally include an income measure (GDP) as well as exports and/or imports, partly supplemented by further variables. Thereby, the most popular theoretical relationships may stem from import functions and export-led growth: The former traditionally explains imports by domestic income, representing purchasing power, and the ratio of import to domestic prices. The latter ascribes various preferable income effects to exports: Besides simply increasing aggregate demand, exports can enhance competition, trigger learning processes, exploit scale effects by tapping larger markets and initiate capital inflows. For respective surveys, see Hong (1999) and Giles and Williams (2000).

While these points represent *partial* macroeconomic approaches, the present paper proposes examining bilateral trade connections in a simultaneous fashion, considering domestic and foreign GDP in addition to im- and exports between the respective countries. Certainly, this allows taking the reverse directions to the above-mentioned causalities into account: Efficiency enhancing competition effects clearly carry over to the imports, which might furthermore provide input and technology goods valuable for economic progress. Furthermore, it might be GDP growth causing export development, since domestic supply, price and productivity developments can determine the scope for exports.

The simultaneous multivariate perspective is completed by the remaining potential influences between the four variables of interest: At first, exports mitigate foreign exchange constraints, allowing further imports into the domestic economy. Additionally, the need of inputs in the export industry might raise imports, but just as well, imports supplying essential production material might trigger a reverse causality. Pressure to cope with import competition possibly enables domestic firms to reach or maintain the standard necessary for exporting into the world market. Apart from the trade connection, GDPs might be directly linked through capital flows, technology diffusion, business cycles and such.

Provided the usual result, that GDPs and trade flows are non-stationary, long-run linkages depend on cointegration. Since the price elasticity in import functions is often found insignificant and PPP implies stationarity of the real exchange rate, *bivariate* cointegration between GDP and imports seems possible. Furthermore, following Bernard and Durlauf (1995), real income convergence between different countries implies per capita GDPs cointegrated with the vector  $(1, -1)$ . Import functions and convergence alone can therefore account for a single common stochastic trend in the four time series. Of course,

the remaining above-mentioned relationships may as well affect cointegration.

The list of possible influences does not claim completeness, but all the more stresses the importance of estimating causalities in a simultaneous framework. In this, two features are added to the traditional analysis: First, the relative economic significance of the respective theoretical approaches is explored, and second, the strengths of different countries in influencing their trade flows can be weighed against each other. After introducing the econometric methods in the following section, I present applications to the trade between the US and Euroland, respectively Canada in comparison. The last section concludes.

## 2 Econometric Methodology

The basic data generating process in the econometric procedure is the VAR with lag length  $q + 1$

$$y_t = c_0^* + c_1^*t + c_2d_t + \sum_{i=1}^{q+1} A_i^*y_{t-i} + u_t, \quad (1)$$

where  $y_t$  contains the  $n$  endogenous variables,  $A_i^*$  are  $n \times n$  coefficient matrices and  $u_t$  is an  $n$ -dimensional vector of white noise errors. The deterministic terms are a constant, a linear trend ( $t$ ) and impulse dummies ( $d_t$ ), which guarantee normality of the residuals.

Given the presence of unit roots in the data, according to Johansen (1995), the commonness of  $n - r$  stochastic trends is reflected by a reduced rank of  $A^*(1)$ , with  $A^*(L) = I_n - \sum_{i=1}^{q+1} A_i^*L^i$ . Consequently, one can write  $A^*(1) = -\alpha\beta'$ , where  $\beta$  spans the space of the  $r$  cointegrating vectors, and  $\alpha$  contains the corresponding adjustment coefficients. Granger's representation theorem leads to the VECM

$$\Delta y_t = \alpha(\beta'y_{t-1} + c_0 + c_1(t-1)) + c_2d_t + \sum_{i=1}^q A_i\Delta y_{t-i} + u_t, \quad (2)$$

with  $A_i = -\sum_{j=i+1}^{q+1} A_j^*$ ,  $i = 1, \dots, q$ . This representation assumes the constant and the linear trend absorbed in the cointegrating relation.

The likelihood ratio trace test statistic (Johansen 1994, 1995) for the null hypothesis of at most  $r$  cointegrating relations is given by

$$\Lambda(r) = -T \sum_{i=r+1}^n \log(1 - \hat{\lambda}_i), \quad (3)$$

where  $n$  is the number of endogenous variables and  $T$  the number of observations.  $\hat{\lambda}_i$  denotes the  $i$ -th largest squared sample canonical correlation between  $\Delta y_t$  and the respective cointegrating relation, both corrected for the influence of the remaining regressors. Since the trace test is known to be distorted in small samples, I implement a correction of the test statistic based on the response surface analysis in Cheung and Lai (1993). Critical values are obtained by computing the response surface in Doornik (1998).

Summarising the model causalities, the  $n \times n$  matrix containing all long-run effects between the endogeneous variables can be derived from the VECM moving average representation (Johansen 1995):

$$\Xi = \beta_{\perp} (\alpha'_{\perp} (A - \sum_{j=1}^q B_j) \beta_{\perp})^{-1} \alpha'_{\perp}, \quad (4)$$

with  $\perp$  denoting the orthogonal complement (thus  $\alpha' \alpha_{\perp} = 0$ , where both  $\alpha$  and  $\alpha_{\perp}$  have full column rank).

## 3 Empirical Evidence

### 3.1 Data

This study employs seasonally adjusted quarterly data of US and Euroland (EU-12) GDPs and im-/ exports from 1980:1 until 2006:4. Euro zone trade flows with the US are obtained from the ECB and deflated to the 2000 level using German im-/export prices. Accordingly, GDPs have been deflated to the year 2000 level using implicit price deflators. The US GDP is expressed in euro using the 2000 purchasing power parity conversion factor from the international comparison program of the World Bank. Qualitatively, results are not concerned by the choice of measuring all values in euro (ECU before 1999). Per capita GDPs have been calculated dividing by total population, which was linearly interpolated to gain quarterly values. Trade flows are relative to the population of the respective importing country, but again, this choice did not prove crucial.

Figure 1 presents the logged time series. The GDP development seems relatively symmetric, maybe apart from the economic boom in Euroland after the German reunification, where the US already went through a recession. Im- and export growth clearly exceeded

GDP growth throughout the sample, but trade was substantially hit by the severe recession from 2001.

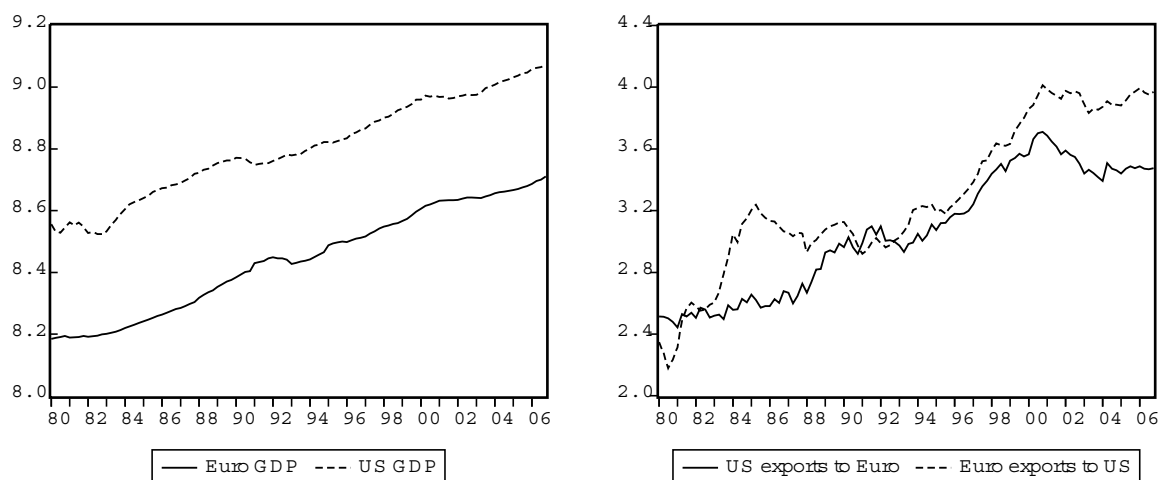


Figure 1: Logged real GDPs and trade flows (2000 per capita EUR)

Before digging into the formal model analysis, the unit root properties of the time series are explored by ADF tests in Table 1. Since no evidence against the null hypotheses can be found and the first differences are clearly stationary, I assume all series integrated of order one.

	Euro GDP	US GDP	Euro imp	Euro exp
t-value	-2.88	-2.72	-1.53	-3.13
lag length	3	2	0	2
$H_0$ cannot be rejected at 10% significance level constant and linear trend included				

Table 1: ADF tests

### 3.2 Cointegration and Model Specification

This section serves to shed light on the cointegrating properties, and thus on the long-run equilibrium behaviour of the data. Therefore, at first model (2) including the US and Euroland GDPs and the mutual im-/exports has to be specified: The information criteria suggested a lag length of one or two quarters, where the latter has been chosen in order to avoid residual autocorrelation. Impulse dummies neutralise extreme residual outliers in 1988:1, 1991:1, 1993:1 and 1995:1. The model specification is supported by Table 2, showing that the LM hypotheses of no autocorrelation up to the respective lag and the Jarque-Bera hypothesis of normality cannot be rejected.

LM(1)	LM(2)	LM(4)	LM(8)	JB
0.21	0.12	0.10	0.25	0.19

Table 2: Specification tests: p-values

The results of the trace tests for the number of cointegrating relations can be found in Table 3. Due to the low p-values, the first two hypotheses can clearly be rejected, and there is even evidence against  $r = 2$  on the ten percent level. Here, I decide to go as far as possible by assuming a single common stochastic trend, but nevertheless, two trends may as well be a sensible choice. This could direct at a possible influence of price variables, which are presently not included.

$H_0 :$	$r = 0$	$r = 1$	$r = 2$	$r = 3$
p-value	0.00	0.01	0.09	0.43

Table 3: Trace tests

### 3.3 Causalities in US-European Trade

Before tackling the main research question of causal effects, the three cointegrating relations are presented (standard errors in parentheses):

$$\begin{aligned}
 im[eu]_t &= \underset{(0.241)}{2.404}gdp[us]_t - \underset{(2.121)}{18.141} \\
 ex[eu]_t &= \underset{(0.595)}{7.031}gdp[us]_t - \underset{(5.073)}{57.675} - \underset{(0.003)}{0.023t} \\
 gdp[eu]_t &= \underset{(-)}{1}gdp[us]_t - \underset{(0.007)}{0.367} + \underset{(0.0001)}{0.001t}
 \end{aligned} \tag{5}$$

Relating all variables to the US GDP is an arbitrary but uncritical choice. The convergence hypothesis has been imposed by restricting the cointegrating coefficient in the last equation to unity (LR p-value = 0.80), and the linear trend in the first equation could be left out (LR p-value = 0.25).

In the following, I present the matrix of long-run effects, where significant values are in bold. Significance is assessed simulating standard errors in a bootstrap procedure with 100,000 replications (see Hall 1992).

$$\Xi = \begin{pmatrix}
 ex[eu] & im[eu] & gdp[eu] & gdp[us] \\
 -0.212 & \mathbf{0.269} & -1.455 & \mathbf{2.604} \\
 -0.622 & \mathbf{0.788} & -4.227 & \mathbf{7.621} \\
 -0.089 & \mathbf{0.113} & -0.591 & \mathbf{1.086} \\
 -0.089 & \mathbf{0.113} & -0.591 & \mathbf{1.086}
 \end{pmatrix} \tag{6}$$



Evidently, the US GDP dominates the system, exerting by far the largest influence on all variables. While the value 2.604 for the income elasticity of US imports (= Euro exports) corresponds to usual results in the trade literature, the reaction of the US exports to US GDP shocks is remarkable: Taken at face value, imports from the US are not determined by European demand, but far more by US supply conditions.<sup>2</sup>

Relatively small but still significant impulses origin in the US export development: For Europe, the US goods may represent valuable inputs for the domestic industrial production, and the US probably takes advantage of growth stimulating as well as balance of payments improving export effects. The qualitative outcome of the total impulse responses can be additionally verified in variance decompositions.

### 3.4 Further Evidence: United States - Canada

The empirical investigation has shown, that US influences dominate trade flows even with Euroland, representing the second economic world power along with the USA. This section offers a plausibility check focusing on the US-Canadian relations. The same comments on data as in the US-European case apply, the trade flows are obtained from Statistics Canada, and unit root tests support the I(1) hypothesis.

The information criteria again favour a lag length of two quarters, confirmed by positive specification tests. Trace tests indicate three cointegrating relations, where the last hypothesis  $H_0 : r = 2$  can be rejected with a p-value of 0.08. The long-run effects obtained from the resulting VECM are presented below. The pattern is quite similar to the European case: US GDP shocks govern the system development, other theoretically expected impacts do not become manifest.

$$\Xi = \begin{matrix} & \begin{matrix} ex[ca] & im[ca] & gdp[ca] & gdp[us] \end{matrix} \\ \begin{pmatrix} 0.178 & -0.447 & 0.119 & \mathbf{3.803} \\ 0.040 & -0.106 & 0.030 & \mathbf{0.885} \\ 0.115 & -0.289 & 0.075 & \mathbf{2.459} \\ 0.115 & -0.289 & 0.075 & \mathbf{2.459} \end{pmatrix} & \end{matrix} \quad (7)$$

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<sup>2</sup>The *extremely* high value of 7.621 might nonetheless be an artefact of the high negative, yet insignificant, estimate for the European GDP.

## 4 Conclusion

This paper proposes analysing regionally specified mutual trade flows in a simultaneous cointegration framework, contrasting with the partial approaches for example on import functions or export-led growth. In the relations of the US with Euroland, respectively Canada, it turns out, that shocks to the US GDP growth rather than European or Canadian impulses dominate both im- and exports.

Although the analysis has been limited to two case studies, it has already become evident, that causalities in international trade do not necessarily follow standard macroeconomic theory. Focusing on further countries in different constellations promises deeper insight into the logic of reciprocal trade flows, comprising the relation to theories on *aggregate* im- and exports. An additional topic for future research might be the inclusion of prices and exchange rates in the simultaneous system of real variables.

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