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Endogenized Trade Shares in a Global Model[1]

by

Bernd Meyer and Christian Lutz

Globally integrated modelling is achieved by employing trade matrices for linking country models. In the case of COMPASS, this is achieved by having time series for trade matrices of 25 commodity groups linking 53 countries and regions. In addition to country models that are estimated econometrically based on empirical data, trade matrices themselves are available over time in response to changing relative prices (endogenous in the model) and other factors. This paper focuses on an attempt to empirically explain the trade shares.

1 Introduction

Prices play an important role for energy demand and supply. In the first place, the shares of the different energy carriers are depending on their relative prices. Secondly, the energy intensities in factor demand of the industries and in household consumption are following price signals. And finally, energy prices influence production costs of all intermediate and final products and have an impact on product prices and demand for the different intermediate and final products. So a shock of energy prices will not only have a direct impact on energy demand, but also have indirect effects resulting from changes in the structure of the economy.

In a global context this means that the competition of the different economies is hit by energy price changes, because countries have a very different usage of energy carriers, energy intensities in production, and very different structures of intermediate and final demand.

In general energy forecasting needs an exact forecast of the world economic developments, and in times of globalisation this can be achieved only by a realistic anticipation of structural change in international trade.

Global energy problems should be discussed in a multisector-multicountry context. The multisector approach is necessary, because energy influences structural change of the economies and is on the other side depending from it. A regional modelling concept is useful, because of the big differences in the economic structures and the energy markets. From the

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view of modelling policy decisions the regions should be politically defined as countries. This makes sense, because policy decisions are reflecting the structures of the economies in question.

The global model COMPASS (Meyer/Uno 1999, Uno/Meyer/Vanwynsberghe/Wang 1999) fulfills these requirements. It depicts the interdependencies of prices and volumes on the different stages of production and consumption for 53 countries and links the economies by a multisector global trade model. The paper at hand focuses the latter part of the model.

In chapter 2 we first give a short overview of the role of the trade model in the system COMPASS and continue with the alternatives of modelling trade in chapter 3. In literature, three approaches for modelling bilateral trade are discussed: The first is the hypothesis of given structures in international trade, which can be rejected with a short view on the facts. The second is modelling import functions based on the Armington hypothesis. This approach is used – for example – in the general equilibrium model GTAP (Hertel/Tsigas 1997). The third approach is modelling export shares. In global multisector models this approach was firstly realised in the INFORUM system (Ma 1997, Nyhus/Ma/Wang 1996). In chapter 3 we discuss the different approaches and prefer the third.

In chapter 4 the logical structure of the trade model of COMPASS is presented. Results of the econometric estimations of the functions of the trade model are discussed in chapter 5. Chapter 6 shows that trade matters: We present the results of two simulations with the whole COMPASS system with constant versus price dependent trade shares. We compare the impacts of a price shock for primary energy on GDP and CO_2 emissions for the G 7 countries. The results show that modelling of trade plays an important role for depicting the interdependency of energy, economy and environment.

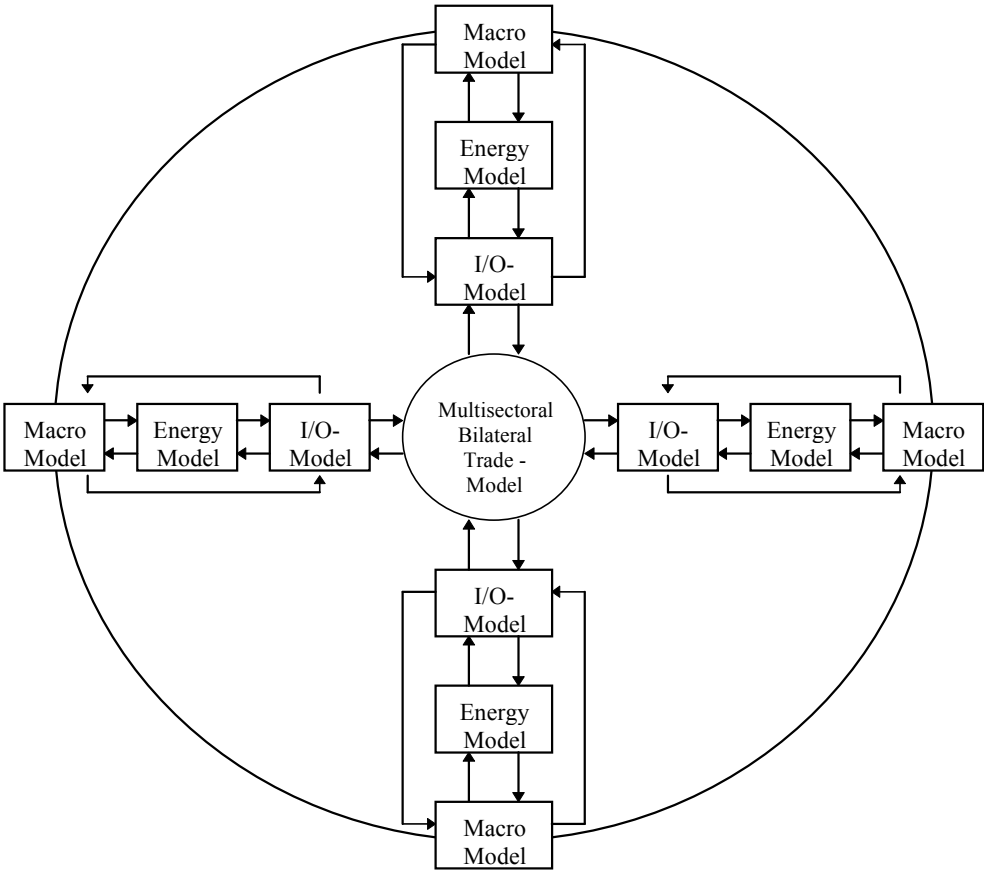
2 The role of the trade model in the global 3E system COMPASS

The structure of the global energy-economy-environment model COMPASS is depicted in figure 1: It shows a wheel, in which the bilateral trade model is the axis. The spokes are the country models, which always consist of a macro model and for most OECD and APEC countries of an input-output model and an energy model. The tyre represents the linkage of the countries via the global equality of savings and investments.

A deeper insight in the linkage of the trade model with the other parts of the system gives figure 2 for one specific country. The global trade model receives a vector of import volumes and export prices from every country model. It calculates for every country a vector of export volumes and import prices.

The input-output models consist of 36 sectors. They get the vector of export volumes and import prices from the trade model and aggregated investment and private and public consumption figures from the macro models and distribute it to 36 sectors. From the energy models they receive prices for the energy carriers. The input-output models calculate the vectors by industry of gross production, intermediate demand, the vector of imports and the vectors for the different components of primary inputs. The input-output models further estimate the vector of unit costs and the vector of prices.

Figure 1: The structure of COMPASS



The macro models aggregate primary income, import volumes and prices coming from the input-output models. They show the redistribution of income between the government, households, enterprises and foreign countries and calculate the disposable income for these institutions, which are important determinants of private and public consumption. The macro models further depict monetary markets and calculate the interest rate and other determinants of investment. The accounting system of the macro models further contains the balance of payments.

The energy models receive the vector of gross production by industry and final demand by branches as well as industry prices, energy import volumes from the input-output models. The trade model delivers energy import prices and energy export volumes to the energy models. The energy models calculate primary and secondary energy demand for 7 carriers in detail, the conversion of energy and CO_2 emissions of the different fossil energy carriers. Based on energy import prices the energy models further determine wholesale and retail prices for the energy carriers, which are delivered to the input-output models.

The 53 countries of the model include all OECD countries, all APEC countries, all OPEC countries, Russia and India (see table 1). For the moment, the structure discussed above is realised for the most important OECD and APEC countries. The others are represented only in the trade model and with macro models, from which 18 models are simple macro simulators.

Figure 2: The linkage of the trade model and the other models for one specific country

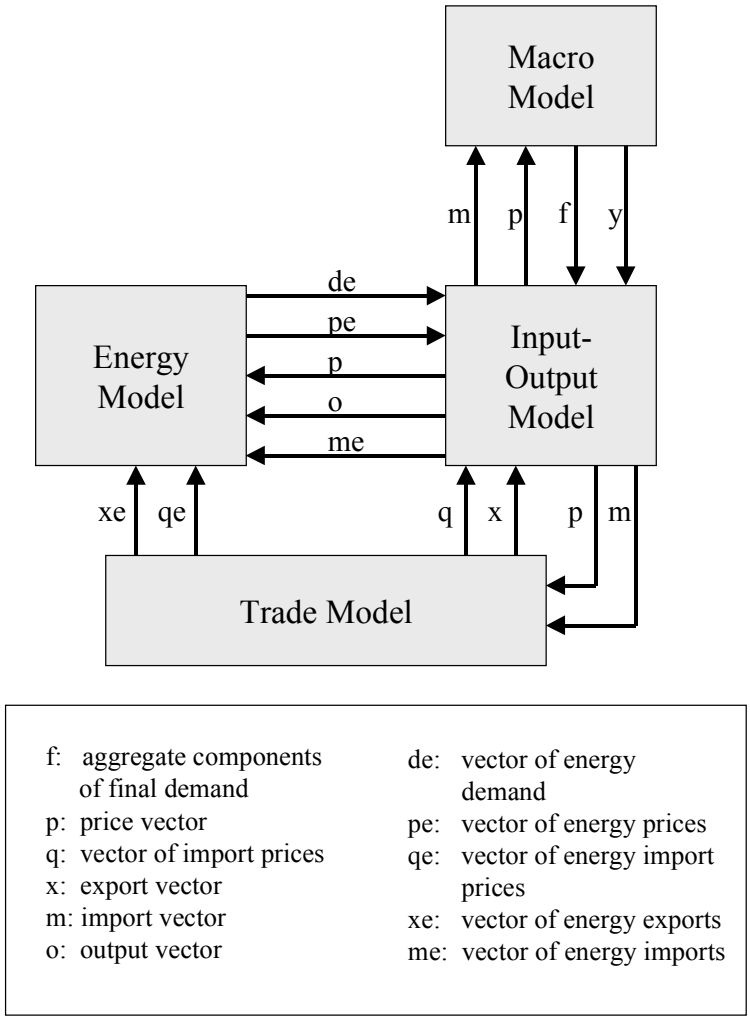


Table 1: Countries and Regions in the trade matrices

1	Belgium and Luxemburg	19	Iran	37	Australia
2	Denmark	20	Iraq	38	Canada
3	France	21	Kuwait	39	USA
4	Germany	22	Oman	40	Brazil
5	Greece	23	Qatar	41	Mexico
6	Ireland	24	Saudi Arabia	42	Venezuela
7	Italy	25	United Arab Emirates	43	Algeria
8	Netherlands	26	Brunei	44	Libya
9	Portugal	27	Hong Kong	45	Angola
10	Spain	28	India	46	Nigeria
11	United Kingdom	29	Indonesia	47	Rest of Europe
12	Austria	31	Korea	48	Rest of Asia
13	Finland	31	Malaysia	49	Rest of Oceania
14	Norway	32	Philippines	50	Rest of North America
15	Sweden	33	Singapore	51	Rest of South America
16	Switzerland	34	Thailand	52	Rest of Africa
17	Former USSR	35	Taiwan	53	Rest of Continents
18	Japan	36	China		

All oil, gas and coal producing countries, the bigger developing countries and the industrialised countries are explicitly part of the system. Additionally seven regions are defined, which include the not explicitly mentioned countries, so that the system closes on the global level. It is guaranteed, that energy demand and supply can be depicted in a global dimension simultaneously with goods and capital markets.

3 Alternatives of modelling bilateral trade

In multisector systems the trade model transforms the vector of import volumes of the different countries into the export volumes of delivering countries. Of course a simple hypothesis is, that the regional structure of the imports of the different countries is constant. In that case we would only need the information of the regional structure of the imports for every country for one year. Given this information the exports of every country could be calculated by definition.

Table 2: World export demand in US-$. Shares of selected countries (in %)

	1980	1996
China	1,083	3,080
Thailand	0,342	1,039
Hong Kong	1,064	3,332
France	5,081	5,401
Germany	8,594	10,107
Italy	3,543	4,880
UK	5,952	5,109
Japan	6,232	6,969
Canada	3,505	4,313
USA	11,281	11,825
Rest	53,322	43,944

A look at the dynamics of international trade raises some doubts. Table 2 compares the shares of some selected countries in total world exports. China, Thailand and Hong Kong show rapidly growing shares coming from a very low level. But also for most of the G 7 countries rising trade shares are observed.

Table 3: World export demand of office and computing machinery in US-$. Shares of selected countries (in %)

	1980	1996
China	0,041	2,176
Thailand	0,024	2,491
Hong Kong	3,870	6,497
France	6,321	2,479
Germany	10,592	3,848
Italy	4,027	2,239
UK	8,785	5,672
Japan	14,427	14,431
Canada	1,008	3,235
USA	31,378	18,708
Rest	19,526	38,222

Table 3 shows, that on the industry level the dynamics of international trade are even stronger. Here we see for the strongly expanding product group "office and computing machinery" the same picture as for the totals concerning China, Thailand and Hong Kong, but now the shares of some G7 countries like USA, Germany, UK and Italy are shrinking. We are convinced, that this dynamic can not be depicted by a trade matrix with constant shares, where every change in the regional structure of exports has to be explained by the regional structure of the import vector.

A more elaborated approach was presented by Armington (1969). He postulated, that the share of country *l* in imports of country *k* of good *i* is depending on the price for good *i*, that country *l* is taking in country *k* relative to the average of the import prices of good *i* over all delivering countries. He further set the hypothesis, that the corresponding price elasticity might be independent from the delivering country.

$$s_{kl}^{i}(t) = b_{kl}^{i} \cdot \left(q_{kl}^{i}(t) / q_{k}^{i}(t)\right)^{\mu_{k}^{i}} \qquad (1)$$

s_{kl}^{i} : share of imports of good *i* in country *k* delivered from country *l*

b_{kl}^{i} : positive constant parameter

q_{kl}^{i} : import price of good *i* in country *k* from country *l* in US $

q_{k}^{i} average of import prices in country *k* over all delivering countries in US $

μ_{k}^{i} : price elasticity of imports of good *i* in country *k*.

The hypothesis is a critical one: It supposes that for example the price elasticity of imported cars in Germany would be the same for Japanese, Korean, American, French and Italian cars. But for many goods consumers have preferences with respect to the delivering country.

The advantage of the hypothesis is that price elasticities can be estimated without having time series of the shares of the delivering countries. A time series of the total of imports of good *i* in country *k* is enough.

For an econometric estimation of the Armington hypothesis see for example Brenton (1989). Often model builders do not estimate on their own, but take estimated price elasticities from literature. They only need one observation of the shares and the relative import prices for one year. With the predetermined price elasticity they can calculate the parameters *b* of equation (1). This procedure is called calibration. With a time series for the import prices they can use equation (1) to forecast the import shares. In this way bilateral trade relations are modelled in the GTAP system (Hertel 1997, Hertel/Tsigas 1997) and in many other CGE models.

If we want to achieve a better representation of the preferences of the agents, we have to estimate specific price elasticities for the delivering countries. To execute the regressions we need a data set, which is at least by factor 15 bigger than in the Armington case. We reject the Armington hypothesis, because we want to have a more adequate analysis and an explicit econometric test of the used equations. This is not possible in the described calibration procedure of CGE modelling.

If we change our perspective from the importing to the exporting country, the share of the imports of good *i* in country *k* coming from country *l* obviously is the share of the exports of country *l* of good *i* to country *k* in the imports of good *i* in country *k*:

$$x_l^i(t) = \sum_{k=1}^{n} s_{lk}^i(t) \cdot m_k^i(t) \qquad (2)$$

$s_{lk}^{i:}$: share of exports of country *l* in the imports of good *i* of country *k*

$x_l^{i:}$: nominal exports of good *i* in country *l*

$m_k^{i:}$: nominal imports of good *i* in country *k*

Following previous work of Klein/Van Petersson (1973), Moriguchi (1973), Hickmann/Lau (1973) and Gana et al. (1979) Ma (1997) specified the following function for the endogenization of the trade shares:

$$\log\left(s_{lk}^i(t)\right) = a_{lk}^i + b_{lk}^i \cdot \log\left[\left(p_l^i(t) / q_k^i(t)\right)\right] + c_{lk}^i \cdot \log\left(K_l^i(t) / K_w^i(t)\right) + d_{lk}^i \cdot t \qquad (3)$$

$p_l^{i:}$: export price of of good *i* in country *l* in US $

$q_k^{i:}$: import price of good *i* in country *k* in US $

$K_l^{i:}$: capital stock invested in production of good *i* in country *l*

$K_w^{i:}$: capital stock invested in production of good *i* in the world

Using this approach Ma estimated price elasticities, that change with the exporting and the importing country. The capital stocks are indicator variables, which shall measure the influence of changes in the quality of the production in the delivering country and its competitors. The time trend has to catch other continuously developing influences. His good results encourage us to follow his approach

4 The logical structure of the trade model in the COMPASS system

As stated above in equation (2) the exports of the model are calculated as follows:

$$x_l^i(t) = \sum_{k=1}^{n} s_{lk}^i(t) \cdot m_k^i(t) \qquad (4)$$

$x_l^{i:}$: nominal exports of country *l* of good *i*

$s_{lk}^{i:}$: share of exports of country *l* in the imports of good i of country *k*

n: number of countries (53)

$m_k^{i:}$: nominal imports of country *k* of good *i*

Here is s_{lk}^i the nominal share of the export of country *l* in the imports of country *k* of good *i* depending from the export price of country *l* relative to the average of the import prices of good *i* in country *k* and a time trend.

$$s_{lk}^i(t) = s_{lk}^i\left[p_l^i(t) / q_k^i(t), t\right] \qquad (5)$$

$s_{lk}^{i:}$: share of exports of country *l* in the imports of good *i* of country *k*

$p_l^{i:}$: price of good *i* in the exporting country *l* in US $

$q_k^{i:}$: import price of good *i* in country *k* in US $

t: time trend

Since capital stocks by industries were not available for the different countries, we had to reduce Ma´s specification.

The import prices of good *i* in country *k* are calculated as weighted averages of the export prices of the different countries. The weights are given with the trade shares

$$q_k^i(t) = \sum_{l=1}^{n} s_{lk}^i(t) \cdot p_l^i(t) \qquad (6)$$

q_k^i : import price of good *i* in country *k*

$s_{lk}^{i:}$: share of exports of country *l* in the imports of good *i* of country *k*

$p_l^{i:}$: price of good *i* in the exporting country *l*

For a better understanding of the role of the trade model in energy modelling, we take a look at the logical flow in the case of a rise of oil prices for example. In equation (6) rising of export prices in oil producing countries increases the import prices for oil in the other countries. This will influence whole sale prices and retail prices in the energy models, which will induce substitution and changes in energy intensities in the energy models of the different countries. The input-output models transform the price changes for energy carriers in domestic price changes for the different goods and calculate reactions on product demand including import demand. From here we come back to the trade model, where in equation (4) the world exports for the different goods are calculated, using trade shares that have been changed by the adjusted relative prices as equation (5) of the trade model shows. The change of the exports then feeds back into the country models and induces further reactions on macro variables, production of industries, demand for commodities and energy demand.

Ma´s trade model is part of the INFORUM system (Nyhus/Ma/Wang 1996). It consists of about 100 product groups compared to only 25 in COMPASS, but only 13 countries compared to 53 in COMPASS. The INFORUM system is limited to only a part of global trade.

5 Empirical results of the estimation of the trade shares

Database of the empirical work are time series of trade matrices of Statistics Canada with about 6000 product groups of the producing sectors from 1980 to 1996 in US Dollars. Services are not included. We aggregated this raw data to the 25 product groups of the 2 digit classification scheme of the OECD input-output tables. The data was also adjusted, so that the identities of the trade matrix in equation (2) are not violated.

We estimated the nominal trade shares by the logarithmic function of (5) with the ordinary least squares (OLS) estimation. The estimated equation can be written as:

$$\log\left(s_{lk}^i(t)\right) = \beta_{1,lk}^i + \beta_{2,lk}^i \cdot \log\left(p_l^i(t)/q_k^i(t)\right) + \beta_{3,lk}^i \cdot \log(t) \qquad (7)$$

The trade shares were estimated automatically using a C++ program. With 25 product groups and 53 times 53 trade shares for each group not less than 70225 trade shares had to be analysed. In the program equation (7) and also its alternatives without a time trend (8) or without price dependency (9) were estimated:

$$\log\left(s_{lk}^{i}(t)\right) = \beta_{1,lk}^{i} + \beta_{2,lk}^{i} \cdot \log\left(p_{l}^{i}(t)/q_{k}^{i}(t)\right) \tag{8}$$

$$\log\left(s_{lk}^{i}(t)\right) = \beta_{1,lk}^{i} + \beta_{3,lk}^{i} \cdot \log(t) \tag{9}$$

If at least one value of the time series was zero, the trade share would be set constant at the level of the last observation. Afterwards, the three equations (7), (8) and (9) were estimated for the remaining variable trade shares. For each trade share the selection procedure was the following: Firstly, the estimated value of the price elasticities $\beta_{2,lk}^{i}$ was restricted to economic plausibility. Because the trade shares are nominal, this price elasticity had to be less than 1. On the other hand extreme price elasticities lower than -10 were rejected:

$$-10 \le \beta_{2,lk}^{i} \le 1 \tag{10}$$

Secondly, the selection followed econometric criteria: The t-values for the estimated coefficients had to be above 2 or below -2. The Durbin-Watson statistic had to be between 1.1 and 2.9. If more than one of the three equations above accomplished these restrictions, the program would choose the estimation with the highest R^2. If all specifications failed, trade share in question would be kept constant in the simulation period.

The algorithm above is applied for 25 product groups and 53 countries, this means for 70225 time series. As 42588 of the time series have one or more zero values, 27637 trade shares were estimated. 12564 equations (45.5 percent of the non zero trade shares) hold the restrictions discussed above and the trade shares can be endogenized. 9300 trade shares (one third of the non zero trade shares) are explained only with a time trend, 8.0% are depending only on prices and 3.8% are determined by prices and trends. So price dependency is given for 3264 of the trade shares.

Table 4 shows these results in detail. The most price depending commodity groups are drugs and medicines (14.3%), food beverages and tobacco (14.0%) and wood and furniture products with 13.6%. In mining and quarrying only 6.7% of the trade shares are depending on relative prices.

6 The relevance of endogenized trade shares: Results of simulations with the whole system

The econometric analysis of price dependency of trade shares has shown that over all sectors not more than 12% of the non-zero trade shares are price dependent. A look at the sector details shows further that the energy products do not belong to the group with the strongest price dependency. Does this mean that prices do not matter?

Without information about the importance of the price dependent shares for the solution of the system the answer is difficult. Of course, there is the expectation, that bigger shares are more price dependent than smaller ones. In this regard, the price dependent trade volume might be

much bigger than 12%. But the importance of a trade share is not only given with its number. It depends also on the import total of that good in the observed country, with which the share is multiplied to get the export of the delivering country. Importance of the trade shares in energy analysis further depends on the product group and its direct and indirect relevance for the energy markets.

Table 4: Results of the estimation of the import shares

		number of coeffi-cients	at least one value of the series is zero	estimated coefficients				constant coeffi-cients
				only with trend	only with prices	prices and trend	total	
1	Agriculture, forestry and fishery	2809	1445	498	118	56	672	692
2	Mining and Quarrying	2809	1753	429	48	23	500	556
3	Food, beverages and tobacco	2809	1198	534	155	70	759	852
4	Textile, apparel and leather	2809	1251	485	123	82	690	868
5	Wood and furniture products	2809	1733	320	97	49	466	610
6	Paper, paper pro. and printing	2809	1473	451	100	61	612	724
7	Industrial Chemicals	2809	1342	546	124	52	722	745
8	Drugs and medicine	2809	1609	433	128	43	604	596
9	Petroleum and coal products	2809	2047	252	72	23	347	415
10	Rubber and plastic products	2809	1755	409	70	38	517	537
11	Non metallic mineral products	2809	1628	396	98	39	533	648
12	Iron and steel	2809	1706	390	76	48	514	589
13	Non ferrous metals	2809	1820	333	68	37	438	551
14	Metal products	2809	1415	442	127	36	605	789
15	Non electrical machinery	2809	1345	519	110	71	700	764
16	Office and comp. machinery	2809	1879	289	80	37	406	524
17	Electrical apparatus nec	2809	1490	453	106	50	609	710
18	Radio, TV and com. Equipment	2809	1695	373	96	33	502	612
19	Shipbuilding and repairing	2809	2327	106	28	8	142	340
20	Other transportation means	2809	2214	168	43	18	229	366
21	Motor vehicles	2809	1687	381	75	57	513	609
22	Aircraft	2809	2310	130	35	16	181	318
23	Professional goods	2809	1433	452	129	54	635	741
24	Other manufacturing	2809	1258	501	104	49	654	897
25	Electricity, gas and water	2809	2775	10	3	1	14	20
	total	70225	42588	9300	2213	1051	12564	15073

It seems that the identification of important trade shares is rather difficult. Therefore, another approach is chosen, which uses all information, that is hidden in the whole COMPASS system: Firstly, a simulation is run with an energy price shock with constant nominal trade shares and then, the same simulation is repeated with endogenized trade shares. A comparison will then give an answer. Of course, also the case of constant nominal shares implicitly assumes price dependency, because the real shares have a price elasticity of -1. So we actually compare two model versions with price dependent trade shares.

In the business as usual (bau) scenario the price for crude oil is fixed at the level of 22$ and the price for coal is also constant for the period 2000 – 2010. In the alternative scenario the oil price grows by 4% per year, an increase of about 50% against the bau in 2010, and the price

for coal in every country follows the path of the price for refined petroleum. We choose these two prices, because in our trade matrix petroleum and coal are a combined product group.

Which effects can be expected? On the energy markets the price shock induces substitution between energy carriers: In final energy demand gas and renewable energy carriers, and in electricity production nuclear energy and renewables will expand their shares. Rising energy prices will reduce the energy intensities of the sectors. Both effects diminish CO_2 emissions. GDP will be reduced, because higher energy prices will raise the output prices of the sectors and this diminishes the demand for goods. This is the reason for a further reduction of CO_2 emissions.

Table 5: Effects of higher energy prices in G7 countries. Deviations of GDP and CO_2 emissions from the bau scenario in the year 2010 in percent

	Constant trade shares		Endogenous trade shares	
	GDP	CO_2	GDP	CO_2
USA	-1.74	-3.01	-1.25	-2.88
Japan	-0.63	-1.36	-0.58	-1.29
Germany	-1.08	-8.90	-0.99	-8.42
France	-1.14	-6.62	-1.60	-6.82
Italy	-0.58	-11.70	-0.43	-11.83
Great Britain	-0.97	-9.27	-1.00	-9.58
Canada	-0.93	-4.68	-0.69	-4.38

Table 5 shows, that for all countries our expectations are fulfilled. But the results are very different in the countries. Let us first have a look at the results for constant nominal trade shares: In the US we observe the strongest reduction of GDP and compared to this a relatively low reduction of CO_2. This is plausible, since a low reduction of CO_2 indicates a low reduction of energy demand and a stronger impact on costs, prices of goods and GDP. In general this relation holds also for the other countries. Only for Japan the picture is different. The reaction of CO_2 emissions is very low. The reason is, that in Japan energy efficiency follows strong long run trends and is not price elastic. The low impact on GDP in Japan can be explained by low reactions of the countries goods prices on changes in energy costs.

In the case of endogenized trade shares the effects on CO_2 emissions do not change drastically. But the impacts on GDP are very different for the US, France and Canada. In the US and Canada we have a 30% and a 26% lower reduction of GDP, whereas in France the reduction of GDP is 40% higher than in the case of constant nominal shares. One interpretation may be, that in the US and Canada the price elasticity of the exports is on average less than one in absolute terms and in France on the average more than one. But there are many other effects like changes in the sector and regional import structures, which are responsible for the result.

7 Conclusions

Global 3E (energy-economy-environment) studies have to analyse questions in a multicountry and multisector approach. The multisector approach is necessary, as changes in energy demand and supply have drastic impacts on the structure of the economy. The multicountry approach is useful, because global policy is done by the governments of really existing countries and not of artificial regions. Policy decisions are always predisposed by the structure of the economy, that has to be modelled. In consequence, we get a huge system with

a big number of countries. The paper at hand shows, that also in the global context of 53 explicitly modelled countries the endogenization of trade shares is possible without the restrictions of the Armington hypothesis, typically used for CGE modelling.

As we could show, endogenized trade shares have influence on the impacts of energy prices on the economy. The deviations from the business as usual scenario in the case of constant shares and in the case of endogenized shares are different. Of course we are presenting results from work in progress. Further work will show, how a variation of the economic and econometric restrictions on the estimation of the trade share functions influences the results.

The impact of the different modelling approaches (constant versus endogenized shares) on the levels of exports and GDP in both scenarios is not discussed. There are very strong differences in respect to the sector and the regional structure of the world economy, but this is beyond the aim of this paper.

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