

EQUIPMENT TRADE AND TRANSPORTATION TRENDS FOR ASIA-EUROPE-AFRICA

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ABSTRACT

Purpose: To provide clues for enhancing multimodal transportation and trade policies, the transportation and machinery equipment trade and transportation trends for the 3 continents of Asia, Europe and Africa, AEA, were analyzed.

Methodology: For the study area a multimodal network was defined. The relevant time-series information was extracted from centralized databases consisting of 4 categories: transportation and machinery equipment trade, transportation, geographical and socio-economic characteristics. The deployed techniques included: preliminary statistical analysis, regression and elasticity analyses, shortest path algorithm, gravity modeling and liner programming.

Findings: The study identified possible relations between trade and transportation. Gravity modeling introduced GDP and transportation variables as the determinant factors for trade. The coefficients of gravity models often showed increasing time trends. The comparison between optimal trade distributions, based on linear programming, and their observed distributions, showed significant differences. Further study of the AEA trades can enhance trade routing and policy development.

Limitations: The study database was limited to information accessible from centralized and international databanks. The trade information was aggregate at national and total transportation and machinery equipment level. The study AEA network was a simplified version of the actual multimodal network. Information about network actual link flows was not accessible. The origin and destination of trades were assumed to be the country's capital.

Originality/value: For the first time, trade and transportation trends for the 3 land connected continents of the AEA were analyzed based on a newly defined multimodal network.

Keywords: Regional transportation, multimodal transportation, trade modeling, gravity modeling, linear programming, Asia, Europe and Africa, freight multimodal routing.

Paper Type: Research paper.

Introduction

Freight transportation plays a key role in trade and economic development. It supports production, trade and consumption activities by ensuring the efficient movement and availability of raw materials, intermediate products and finished goods. Over the years, interest in explicit consideration of commodity and goods movement in the transportation planning has steadily increased (Park and Regan, 2005, Vaziri and Omrani, 2011). A recent study suggested that 10% increase in transportation costs would reduce 20% of trade volume (Rodrigue et al., 2009). The United Nations Commodity Trade Statistics Division confirms that more than one third of total value of global trade volume is related to transportation and machinery equipment (Comtrade, 2010). Transportation cost has a significant effect on final goods' prices, and trade partners are expected to select the nearest demand and supply nodes. The effect of the transportation distance and cost on the transportation and machinery equipment trade is a subject of debate as many geopolitical and economic factors can play significant roles. The continents of Asia, Europe and Africa, AEA, have the advantage of land connectivity and are accommodating more than 80% of world population. Around 90% of total export of European, 79% of Asian and 76% of African countries went to other countries in Asia, Europe and Africa during 2009 (Comtrade, 2010).

The study reported herein tries to shed some light on the effect of transportation on the AEA intra and intercontinental transportation and machinery equipment trade. The relevant time-series data were extracted from centralized and international databases. The database consisted of variables grouped into 4 categories: transportation and machinery equipment trade, transportation, geographical and socio-economic characteristics. The study deployed techniques included: preliminary and univariate statistical analysis, regression analysis, shortest path algorithm, elasticity analysis, sensitivity analysis, gravity modeling and liner programming. The international trade flows were analyzed for a 40 year period covering 1965 to 2005. The trans-continental multimodal transportation network covered 125 countries of AEA (Vaziri and Dashtestaninejad, 2010).

Database Development

The study database consisted of pertinent time-series information for international trade extracted from international and centralized databases. It comprised of country's data in 4 categories: transportation and machinery equipment trade, TMT, transportation, TRS, socio-economic, SEC, and geographical, GEO. The time-series covered a 40 year period of 1965 to 2005. For each year of the study period, 9 variables were finally selected for detail analysis as shown in Table 1. The geographical scope covered 125 countries, 45 in Asia, 31 in Europe and 49 in Africa. The TMT data were extracted from the United Nations Commodity Trade Statistics Division databanks (Comtrade, 2010). The SEC and GEO were also extracted from United Nations databases (Vaziri and Omrani, 2011). The TRS data were developed from United Nations sources (Vaziri and Dashtestaninejad, 2010). The AEA multimodal transportation network, with distance and cost attributes, consisted of 5323 nodes, including the 125 capital nodes. Deploying network analysis algorithms, such as shortest path algorithm, TRS variables were determined for capital cities of country pairs i and j . The C_{ij}^{MM} is the optimal transportation cost for the multimodal network which included all the 4 modes of highway, H, railway, R, sea, S and air, A. The D_{ij}^{HRS} is the optimal distance with 3 modes of highway, H, Rail, R, and sea, S. The D_{ij}^{Air} is the direct air distance for air mode, A.

Table 1: Data base structure and description

No.	Category	Symbol	Unit	Description	Number of observation
1	TMT	T_{ij}^{EX}	\$	Export of transportation and machinery equipment, from country i to country j in dollar	125×125
2		T_{ij}^{IM}	\$	Import of transportation and machinery equipment, from country j to country i in dollar	125×125
3	TRS	C_{ij}^{MM}	\$/unit of transport	Multimodal transportation cost between country i and country j	125×125
4		D_{ij}^{HRS}	Km	Multimodal distance between country i and country j	125×125
5		D_{ij}^{Air}	Km	Direct distance between country i and country j	125×125
6	GEO	A_i	Thousand Km ²	Area of country i	125
7		L_i	Dummy	Landlocked of country i	125
8	SEC	P_i	Thousand persons	Population of country i	125
9		GDP_i	\$/year	Gross domestic product of country i	125

To shed some light on database structure and scope, preliminary univariate and multivariate statistical analysis was performed. As an example, the summary of preliminary univariate statistical analysis for the year 2005 is presented in Table 2. Furthermore, correlation matrices were developed showing the existence of significant correlation between variable pairs. They often showed significant correlations between trade, GDP and transportation variables. The negative correlations between transportation and trade variables suggested the negative influence of transportation cost and distance on trade.

Table2: Univariate statistical analysis for year 2005

No.	Var.	Unit	Min	Max	Mean	St. dev.	Coef. of var.	Valid cases
1	T_{ij}^{EX}	\$	0	7.64×10^{10}	1.84×10^8	1.69×10^9	8.75	12524
2	T_{ij}^{IM}	\$	0	5.68×10^{10}	1.74×10^8	1.47×10^9	8.46	12400
3	C_{ij}^{MM}	\$/unit of transport	24	7004	2000	991.21	0.49	15500
4	D_{ij}^{HRS}	Km	60	18268	6720	3566.85	0.53	15500
5	D_{ij}^{Air}	Km	12	14748	5240	2899.47	0.55	15500
6	A_i	Thousand Km ²	0.06	17075	678	1794.20	2.65	125
7	L_i	Dummy	0	1	0.74	0.44	0.60	125
8	P_i	Thousand persons	30	1.31×10^6	4.43×10^3	1.55×10^5	3.50	125
9	GDP_i	\$/year	3.02×10^8	4.55×10^{12}	2.24×10^{11}	6.10×10^{11}	2.72	123

Trade Modeling

Several trade modeling approaches can be distinguished: a microscopic level with a microeconomic point of view, a meso level with spatial interaction modeling, and a macroscopic level with a macroeconomic point of view. The spatial interaction modeling approach was found suitable for the study database. The models often used for spatial interaction modeling are based on gravity distribution and linear programming modeling (Vaziri and Omrani, 2011).

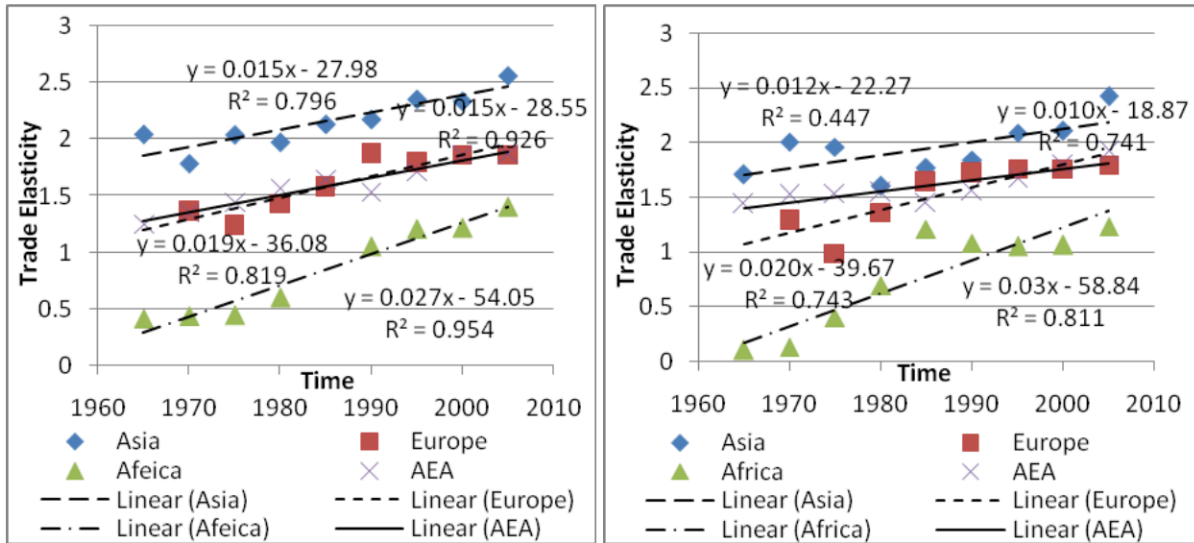
The gravity model was originated by Newton gravity rule of mechanical physics. The trade gravity model between two countries in its basic form assumes trade increases with country size or incomes and decreases with spatial impedance. Three different spatial trade impedance variables were defined and examined in this study: the conventional air distance and the multimodal distance and costs. Deploying stepwise regression analysis and a confidence level of 95%, for each year of the study database, gravity models of transportation and machinery equipment trade were developed. Table 3 shows the modeling results for 1965 to 2005 for five year intervals for the AEA 125 countries. The variables are defined as in Table 1 and the trade variable C7subscript reflects that transportation and machinery equipment has code 7 in the UN commodity system.

Table3: Transportation and machinery equipment gravity models

Year	Model	R ²	Model	R ²
1965	$T_{ij,C7}^{EX} = 10^{-5.103} \frac{GDP_i^{1.318} GDP_j^{0.225} POP_j^{0.230} 10^{0.372LL_j}}{D_{ij}^{HRS1.430} A_i^{0.286} A_j^{0.106}}$	0.59	$T_{ij,C7}^{IM} = 10^{-4.066} \frac{GDP_i^{0.118} GDP_j^{1.304} POP_i^{0.601} 10^{0.234LL_i}}{D_{ij}^{HRS0.959} C_{ij}^{MM0.791} A_i^{0.149} A_j^{0.346} 10^{0.304LL_j}}$	0.60
1970	$T_{ij,C7}^{EX} = 10^{-6.769} \frac{GDP_i^{1.386} GDP_j^{0.427} 10^{0.250LL_j}}{D_{ij}^{HRS1.262} POP_i^{0.159} 10^{0.203LL_i} A_i^{0.278}}$	0.58	$T_{ij,C7}^{IM} = 10^{-10.042} \frac{GDP_i^{0.534} GDP_j^{1.631} 10_i^{0.251LL_i}}{D_{ij}^{HRS1.059} POP_j^{0.385} A_j^{0.377} 10_j^{0.178LL_j}}$	0.60
1975	$T_{ij,C7}^{EX} = 10^{-8.763} \frac{GDP_i^{1.482} GDP_j^{0.512} 10^{0.500LL_j}}{D_{ij}^{HRS1.515} C_{ij}^{MM0.791} A_i^{0.517} 10^{0.229LL_i}}$	0.56	$T_{ij,C7}^{IM} = 10^{-9.237} \frac{GDP_i^{0.512} GDP_j^{1.143} POP_j^{0.109} 10^{0.375LL_i}}{D_{ij}^{HRS1.169} A_j^{0.641} 10^{0.166LL_j}}$	0.58
1980	$T_{ij,C7}^{EM} = 10^{-10.694} \frac{GDP_i^{1.590} GDP_j^{0.528} 10^{0.445LL_j}}{D_{ij}^{HRS1.197} A_i^{0.553} A_j^{0.081} 10^{0.226LL_i}}$	0.60	$T_{ij,C7}^{IM} = 10^{-11.070} \frac{GDP_i^{0.521} GDP_j^{1.529} POP_i^{0.100} POP_j^{0.213} 10^{0.340LL_i}}{D_{ij}^{Air0.721} C_{ij}^{MM0.518} A_i^{0.141} A_j^{0.640} 10^{0.389LL_j}}$	0.58
1985	$T_{ij,C7}^{EX} = 10^{-14.853} \frac{GDP_i^{1.963} GDP_j^{0.657} 10^{0.362LL_j}}{D_{ij}^{HRS1.163} POP_i^{0.364} A_i^{0.449} A_j^{0.100} 10^{0.133LL_i}}$	0.63	$T_{ij,C7}^{IM} = 10^{-11.973} \frac{GDP_i^{0.555} GDP_j^{1.671} POP_i^{0.231} 10^{0.174LL_i}}{D_{ij}^{HRS0.611} C_{ij}^{MM0.606} A_i^{0.169} A_j^{0.536} 10^{0.476LL_j}}$	0.60
1990	$T_{ij,C7}^{EX} = 10^{-11.987} \frac{GDP_i^{1.564} GDP_j^{0.582} POP_i^{0.118} 10^{0.198LL_j}}{D_{ij}^{HRS0.904} C_{ij}^{MM0.267} A_i^{0.427} A_j^{0.114}}$	0.63	$T_{ij,C7}^{IM} = 10^{-11.114} \frac{GDP_i^{0.598} GDP_j^{1.487} POP_i^{0.204}}{D_{ij}^{Air0.564} C_{ij}^{MM0.806} A_i^{0.158} A_j^{0.374} 10^{0.208LL_i}}$	0.66
1995	$T_{ij,C7}^{EX} = 10^{-8.211} \frac{GDP_i^{1.276} GDP_j^{0.537} POP_i^{0.114} POP_j^{0.166} 10^{0.143LL_j}}{D_{ij}^{Air0.847} C_{ij}^{MM0.749} A_i^{0.324} A_j^{0.058} 10^{0.084LL_i}}$	0.63	$T_{ij,C7}^{IM} = 10^{-9.520} \frac{GDP_i^{0.558} GDP_j^{1.529} POP_i^{0.265} 10^{0.120LL_i}}{D_{ij}^{HRS0.756} C_{ij}^{MM0.754} A_i^{0.174} A_j^{0.271} 10^{0.086LL_j}}$	0.66
2000	$T_{ij,C7}^{EX} = 10^{-9.879} \frac{GDP_i^{1.444} GDP_j^{0.617} POP_j^{0.127} 10^{0.076LL_j}}{D_{ij}^{HRS0.959} C_{ij}^{MM0.779} A_i^{0.188} 10^{0.288LL_i}}$	0.62	$T_{ij,C7}^{IM} = 10^{-10.514} \frac{GDP_i^{0.656} GDP_j^{1.404} POP_i^{0.204} POP_j^{0.115}}{D_{ij}^{Air0.760} C_{ij}^{MM0.985} A_i^{0.060} A_j^{0.297} 10^{0.210LL_j}}$	0.64
2005	$T_{ij,C7}^{EX} = 10^{-11.498} \frac{GDP_i^{1.550} GDP_j^{0.622} POP_i^{0.092} POP_j^{0.166} 10^{0.090LL_j}}{D_{ij}^{HRS1.038} C_{ij}^{MM0.760} A_i^{0.327} 10^{0.165LL_i}}$	0.64	$T_{ij,C7}^{IM} = 10^{-11.548} \frac{GDP_i^{0.633} GDP_j^{1.511} POP_i^{0.289} POP_j^{0.212}}{D_{ij}^{Air0.897} C_{ij}^{MM0.989} A_i^{0.106} A_j^{0.427} 10^{0.099LL_i} 10^{0.126LL_j}}$	0.64

The table confirms the negative relationship between transportation and machinery equipment trade and the transportation variables. To more distinctly highlight the effect of transportation variables on the developed models, a second and refined set of models were developed using only GDP and one of the transportation variables C_{ij}^{MM} , D_{ij}^{HRS} and D_{ij}^{Air} . These models were similar to Table 3 in terms of coefficient sign and value, and R².

In a gravity model, the elasticity of the dependent variable with respect to an independent variable is its calibrated coefficient (Vaziri and Omrani, 2011). To evaluate the sensitivity of trade with respect to transportation variables from 1965 to 2005, variation of calibrated coefficients were studied. Linear regression models were calibrated to estimate the trend of coefficient of C_{ij}^{MM} , D_{ij}^{HRS} and D_{ij}^{Air} . For

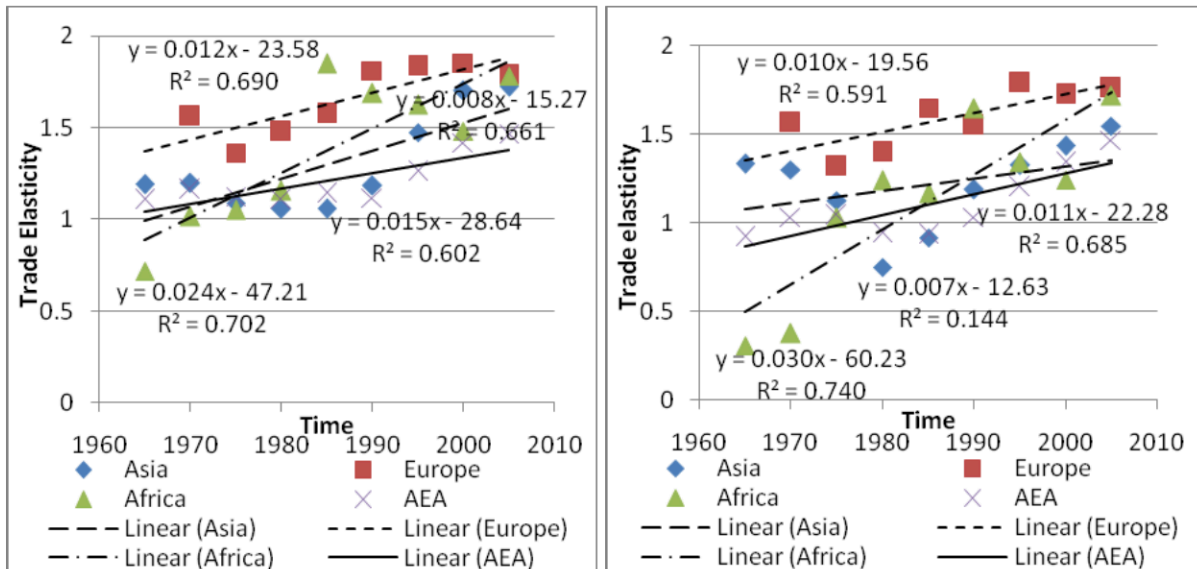


within AEA and continents separately, the results of linear regression analysis for the refined set of gravity models are presented in Figures 1 to 3. Upward trends of transportation coefficients for within

a) Export

b) Import

Figure 1: Trends of trade elasticity with respect of C_{ij}^{MM}



a) Export

b) Import

Figure 2: Trends of trade elasticity with respect to D_{ij}^{HRS}

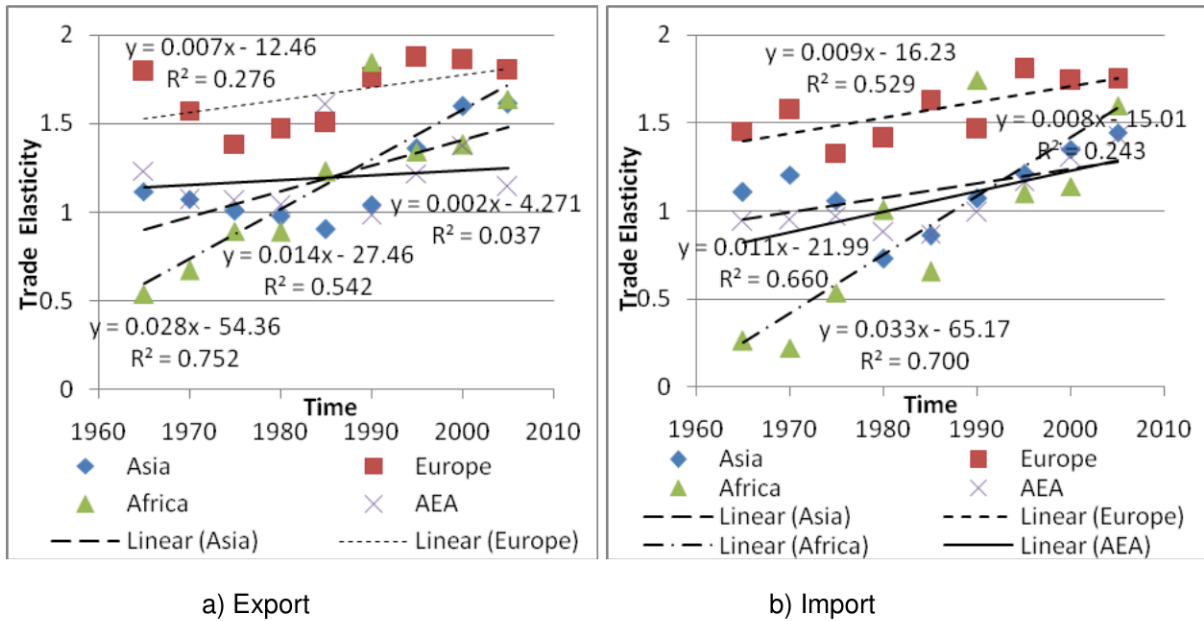


Figure 3: Trends of trade elasticity with respect to D_{ij}^{Air}

AEA and continents separate are evident in these figures. The elasticity is often more than one, reflecting that trade was elastic with respect to transportation variables. Furthermore, R^2 's show that fitness of linear models differ among continents, nevertheless are often at acceptable levels.

The results of linear regression modeling revealed that the transportation sensitivity of trade has increased over time. The figures show that Asia had the highest and Africa the lowest trade elasticity's with respect to transportation cost, with AEA and Europe trade elasticity's in between of Asia and Africa. With respect to transportation distance, Europe had the highest and Africa the lowest trade elasticity in almost all of the cases. Africa had lowest transportation sensitivity of trade although its sensitivity showed higher gradient of improvement since 1965. This could be of great interest to international organizations and national policy makers to further develop and finance Africa's transportation infrastructure and facilities. The study rejects the notion of the "death of distance", as some past studies were advocating (Vaziri and Omrani, 2011). The upward trend of distance and cost effect on trade shows the aforesaid hypothesis is not always applicable at least for the global transportation and machinery equipment trade. In contrast, AEA countries tried to reduce transportation costs over time by choosing "closer" suppliers of goods. Nevertheless, this was far from linear programming optimal solutions.

To determine potentials for transportation improvement of trade, linear programming, LP, was deployed to compare observed trade distributions with its possible optimal values. The objective function, reflecting AEA or continents separately total transportation "cost", was minimized using simplex algorithm. The LP determined possible redistribution of trade with the consideration of the trade supply and demand constraints of individual countries. Due to language, historical, socio-cultural and geopolitical reasons, it is not always possible to deploy LP solution in actuality; nevertheless it provides clues to the potentials for improvement. Tables 4 and 5 show the results of LP for transportation and machinery equipment trade for multimodal networks for AEA and each continent separately. The tables show the percentage of possible improvement if trade was redistributed based on optimal LP solutions. The improvement potentials were often more for Europe than Asia and Africa. Significant trade improvement potentials were observed for all the 125 countries of AEA.

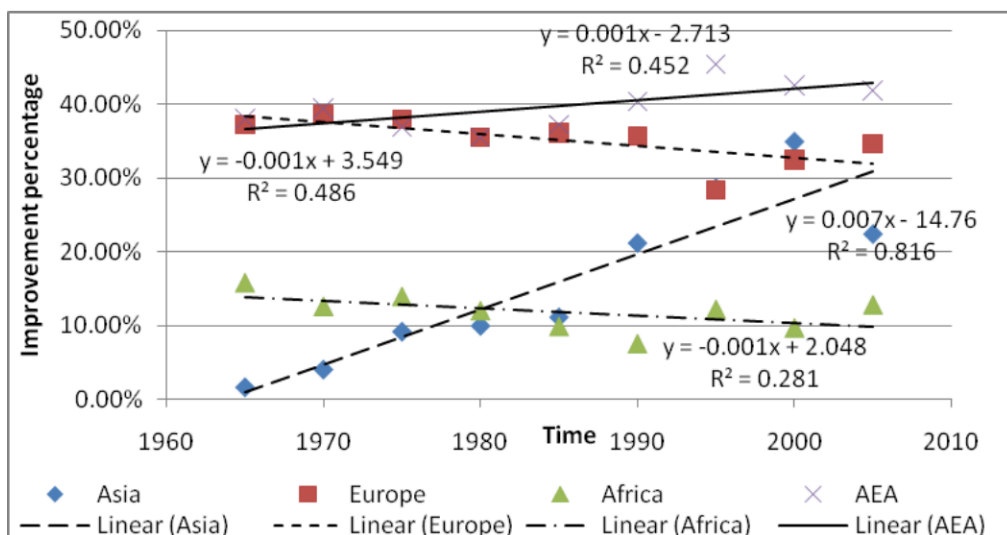
Table 4: Possible improvements in export trade redistribution

Year	Based on C ^{MM}				Based on D ^{HRS}			
	AEA	Asia	Europe	Africa	AEA	Asia	Europe	Africa
1965	37.98%	1.68%	37.30%	15.85%	44.21%	1.51%	39.86%	40.76%
1970	39.45%	4.07%	38.67%	12.60%	43.70%	3.97%	44.59%	33.44%
1975	36.87%	9.19%	38.05%	13.95%	40.97%	5.59%	46.49%	29.24%
1980	35.51%	9.99%	35.55%	12.00%	40.49%	7.50%	39.89%	19.67%
1985	37.21%	11.15%	36.13%	9.83%	43.92%	11.16%	39.58%	26.60%
1990	40.43%	21.19%	35.71%	7.44%	49.11%	23.50%	37.65%	16.85%
1995	45.45%	28.64%	28.38%	12.18%	59.29%	32.99%	51.51%	28.70%
2000	42.60%	34.91%	32.49%	9.63%	55.52%	40.62%	35.42%	8.94%
2005	41.85%	22.41%	34.65%	12.81%	54.16%	34.53%	36.64%	16.60%

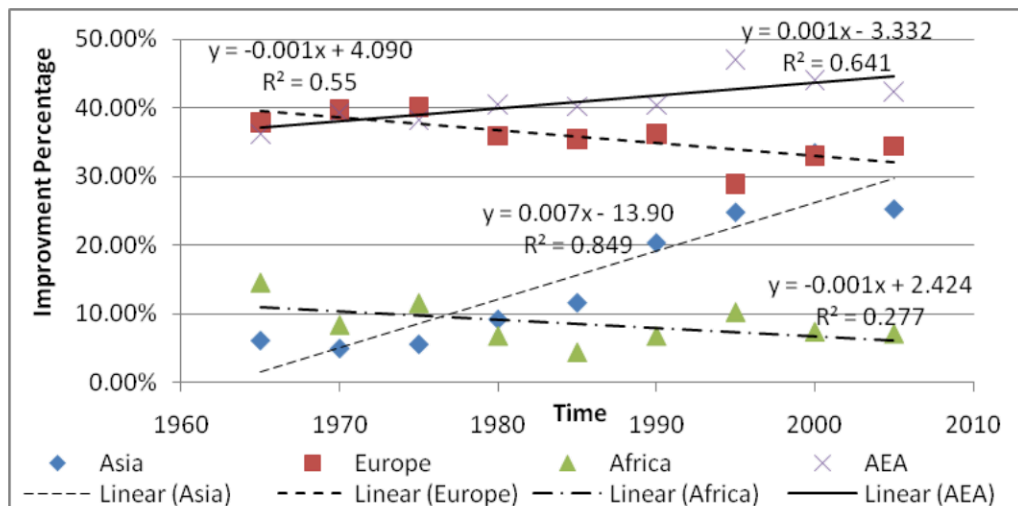
Table 5: Possible improvements in import trade redistribution

Year	Based on C ^{MM}				Based on D ^{HRS}			
	AEA	Asia	Europe	Africa	AEA	Asia	Europe	Africa
1965	36.13%	6.03%	37.93%	14.52%	42.04%	9.81%	40.85%	29.46%
1970	39.24%	4.86%	39.78%	8.35%	46.17%	4.03%	42.17%	24.72%
1975	38.27%	5.48%	40.15%	11.54%	44.21%	7.48%	41.90%	36.27%
1980	40.44%	9.13%	35.92%	6.74%	45.26%	6.07%	40.42%	19.63%
1985	40.18%	11.55%	35.48%	4.35%	49.23%	14.69%	39.69%	55.75%
1990	40.40%	20.32%	36.21%	6.75%	48.45%	20.92%	38.53%	18.31%
1995	47.08%	24.78%	28.92%	10.21%	60.76%	30.01%	32.46%	24.82%
2000	43.99%	33.46%	33.03%	7.37%	56.76%	38.93%	36.20%	9.53%
2005	42.31%	25.25%	34.43%	7.08%	54.19%	36.06%	36.63%	10.31%

To determine the trends of improvement potentials through time, regression models for AEA and continents separately were developed. The results are shown in Figures 4 and 5. As the figures show, the potentials for Asia significantly grew over time compared with Europe and Africa. In other words, Asia trade showed a diverge trend from LP optimal distributions through period of 1965 to 2005. Where as Europe and Africa trade showed a converge trend to LP optimal distributions.



a) Export



b) Import

Figure 5: Export and import improvement potentials through time based on C_{ij}^{MM}

Linear approximation model revealed that coefficient of time variable for continents were significantly different. Over the study period, the difference in percentage between observed and optimal distributions for transportation and machinery equipment trade decreased for Europe and Africa, in contrast for Asia and AEA.

Conclusion

The study shed some light on transportation and machinery equipment trade trends in 3 continents of Asia, Europe and Africa, AEA. The trade and transportation among 125 countries, based on spatial interaction models during the period of 1965 to 2005, were assessed and evaluated. The study AEA transportation multimodal network consisted of 5323 nodes connected by highway, railway, air and sea links. The study database consisted of national time-series information for 9 pertinent variables: transportation and machinery equipment import and export trades between country pairs, multimodal optimal transportation cost between country pairs, multimodal optimal distance between country pairs, air distance between country pairs, GDP, population, area and landlocked. The study deployed techniques included: preliminary and univariate statistical analysis, regression analysis, shortest path algorithm, elasticity analysis, sensitivity analysis, gravity modeling and liner programming.

The database preliminary statistical analysis showed significant correlations between trade, GDP, and transportation variables. The cross-sectional gravity confirmed that transportation and machinery equipment trade between country pairs are related to their GDP's and transportation costs or distances. Elasticity analysis based on the developed gravity models highlighted that the transportation variables seems to play an important role on AEA region transportation and machinery equipment trade and this effect is increasing in parallel with globalization trends over time for the whole AEA region, and its 3 continents. This effect is expected to be even more significant in the near future with the current growing trends of energy price and economic crises. Trade elasticity with respect to cost and distance had highest values for Asia and Europe respectively. Africa had lowest transportation sensitivity of trade among studied areas although its trade sensitivity grew significantly over time. The optimal transportation and machinery equipment trades, based on linear programming solutions, were compared with observed distributions. Comparison revealed that up to 60% of the AEA total transportation costs can be reduced if the observed trades follow the LP optimal distributions. The differences mostly attributed to the historical, socio-cultural, language, geopolitical and other factors which were not considered in this later optimization exercise. Percentage of possible improvement decreased during the study period for Europe and Africa. In contrast, percentage of possible improvement for AEA and Asia trade increased, indicating that observed distributions diverged from the optimums. This study was a preliminary step toward the AEA time-series transportation and trade appraisal. Deploying the study methodology and results can enhance pertinent policy making and infrastructure development at the AEA national and regional levels. The study database and results were limited to extractable information from centralized and accessible international databanks, nevertheless, the same methodology can be used for other geographical and spatial/temporal information to enhance trade and commerce.

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