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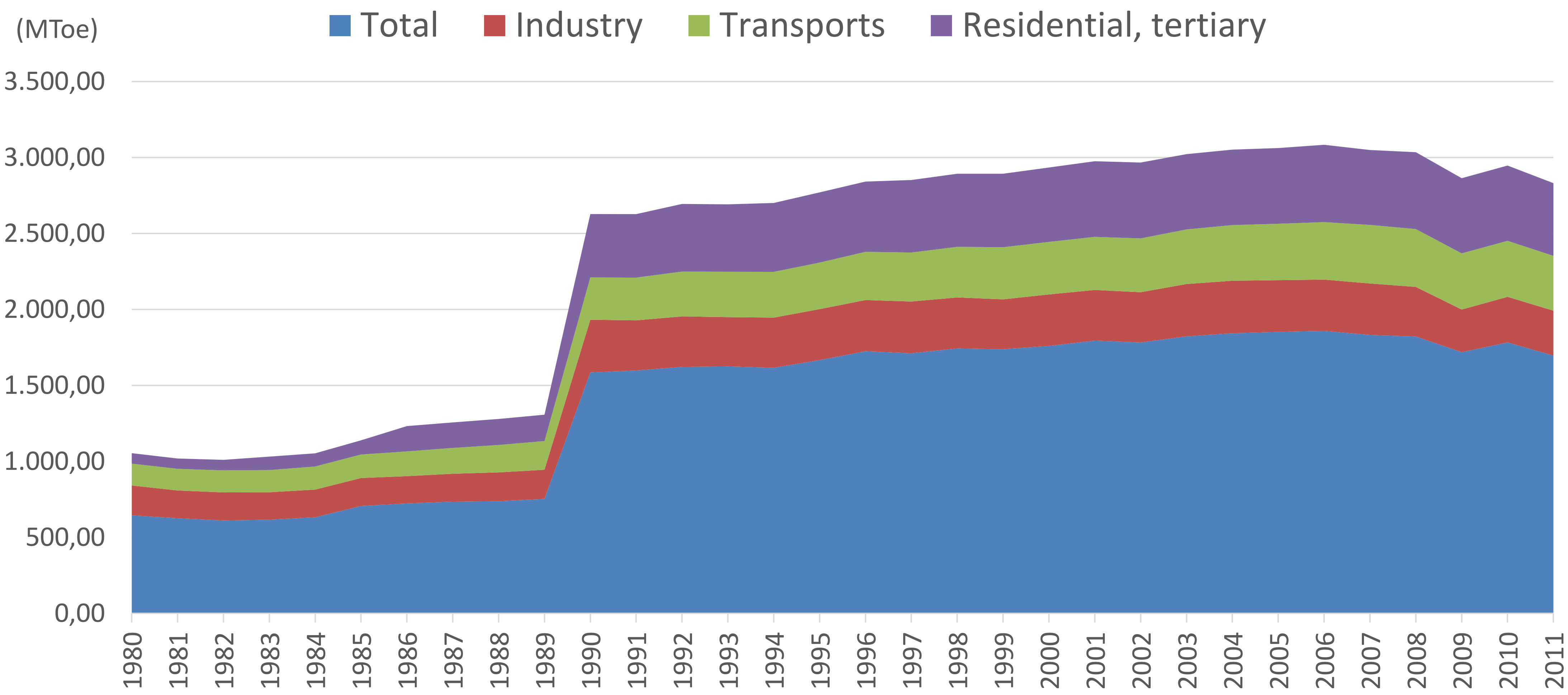
D7.11

Case study: Paper on the energy efficiency evolution in the European road freight transport sector

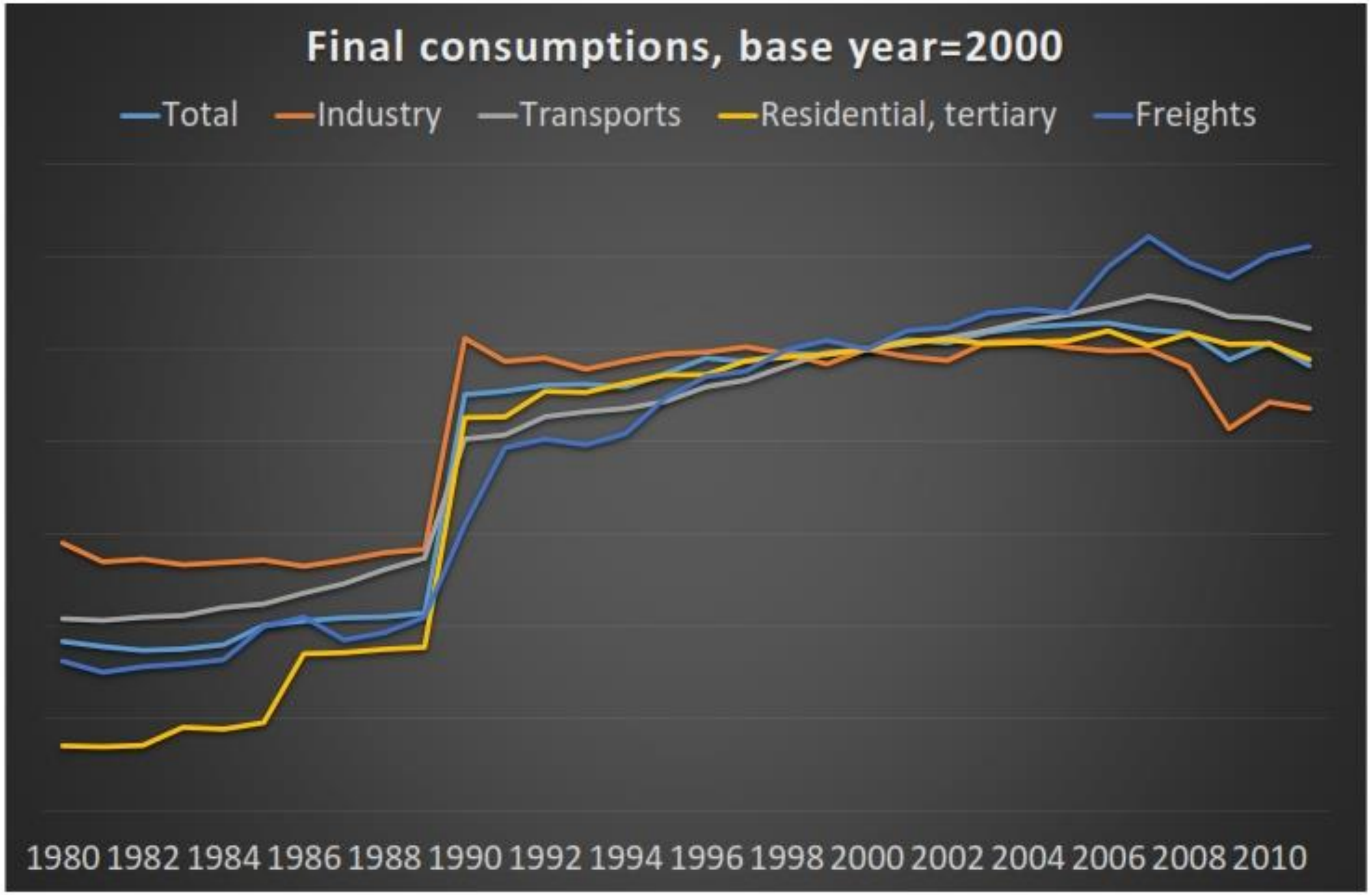
Riccardo Basosi and Franco Ruzzenenti

EU28: energy breakdown



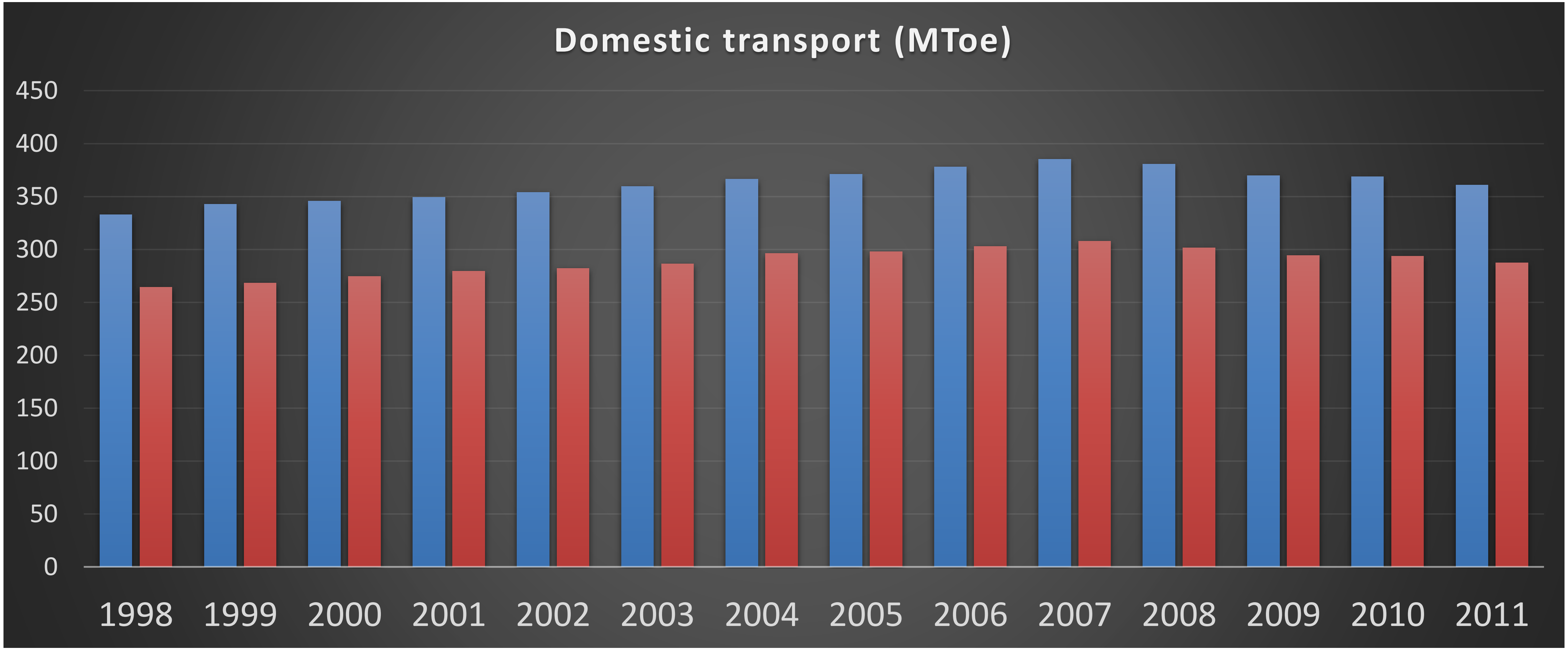
 Source : Odyssee

Freights transports: highest growth rate (EU28)



Source : Odyssee

80% is domestic transports (EU28, final energy consumption)



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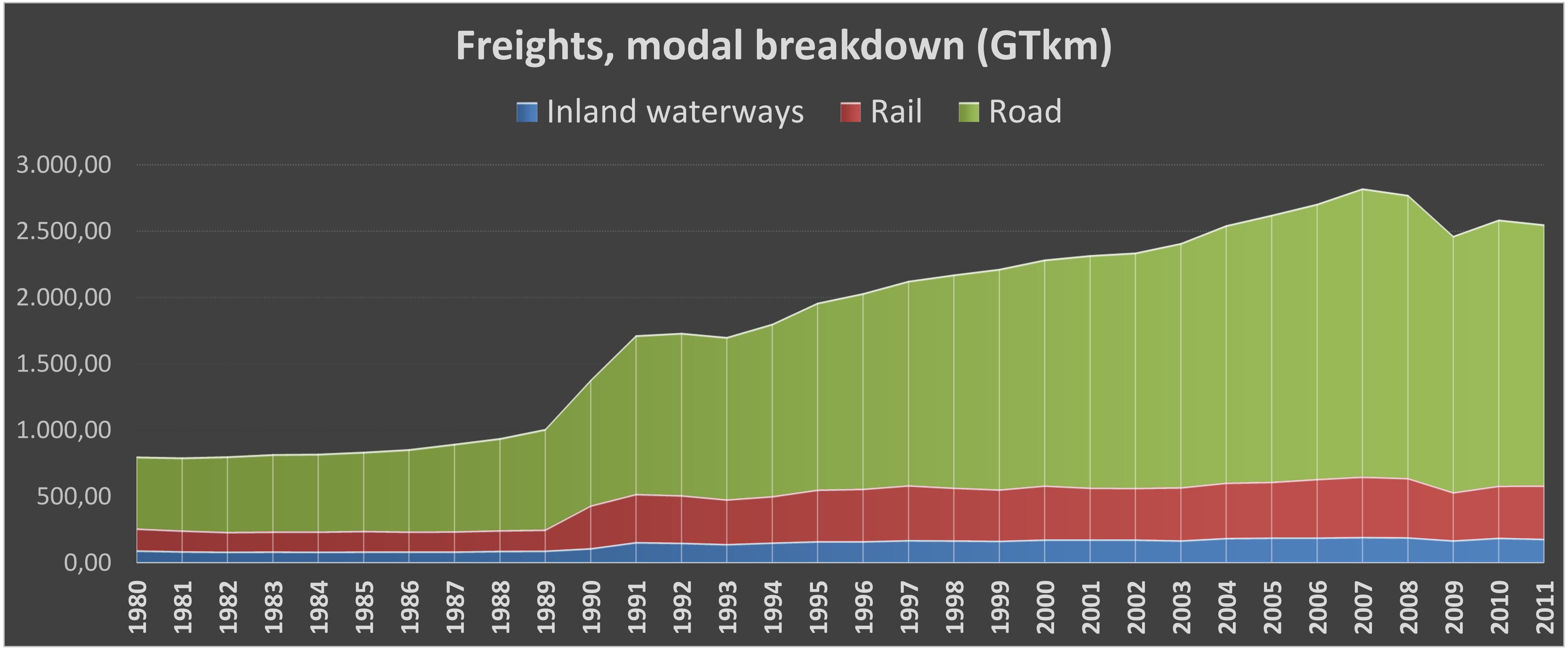
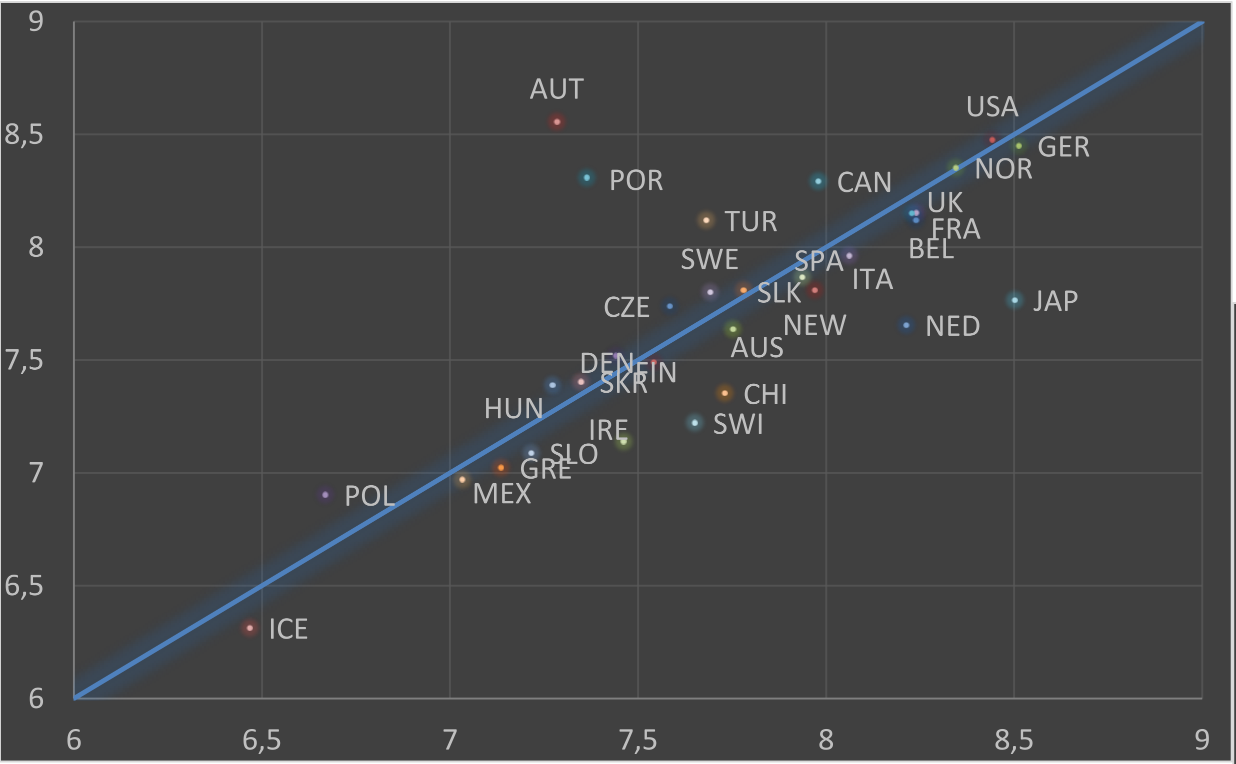
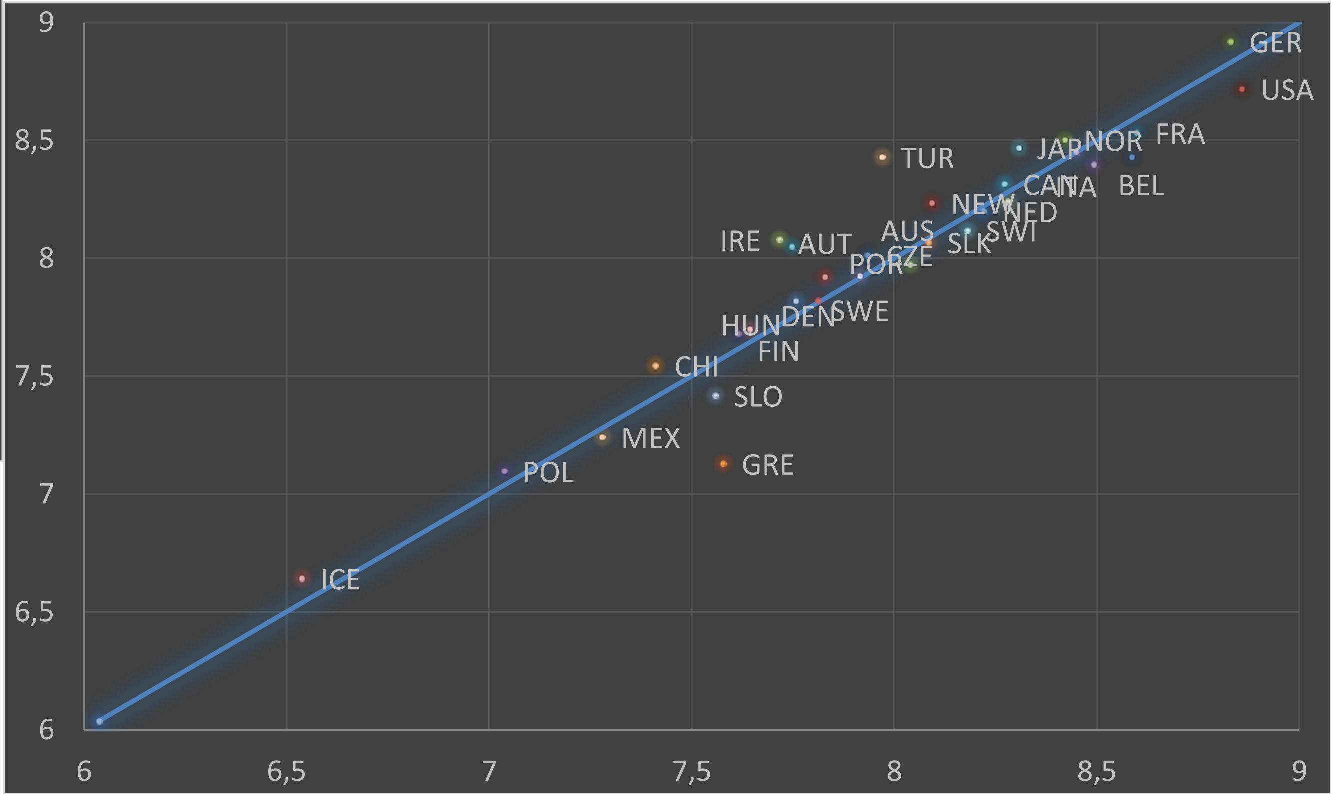
Freights growth in EU was driven only by road



Source : Odyssee

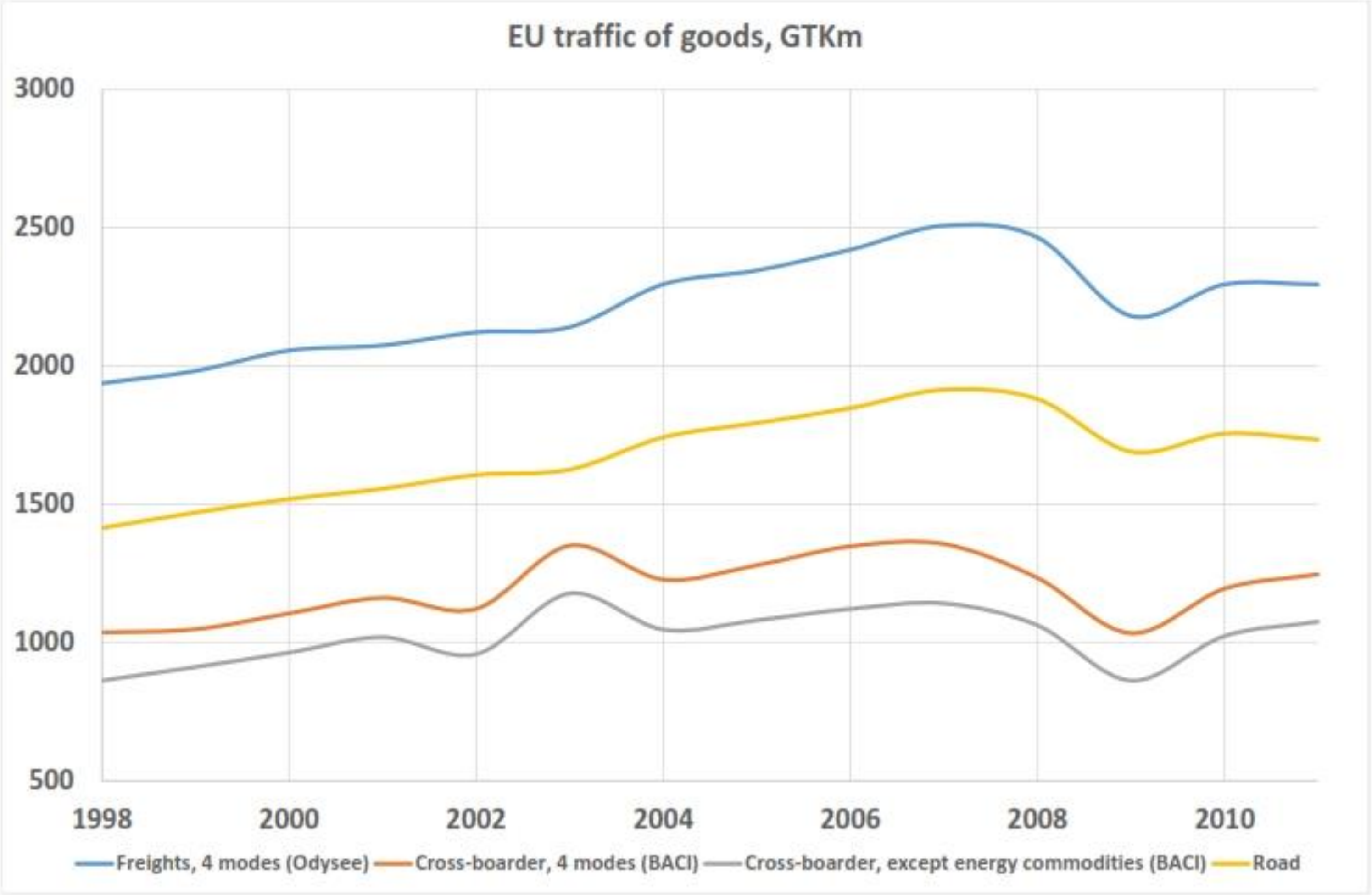
OECD 2010, Import (x) vs Export (y) in mass (ton) and money (M$): mass is broadley distributed!





Freights: total and cross-boarders

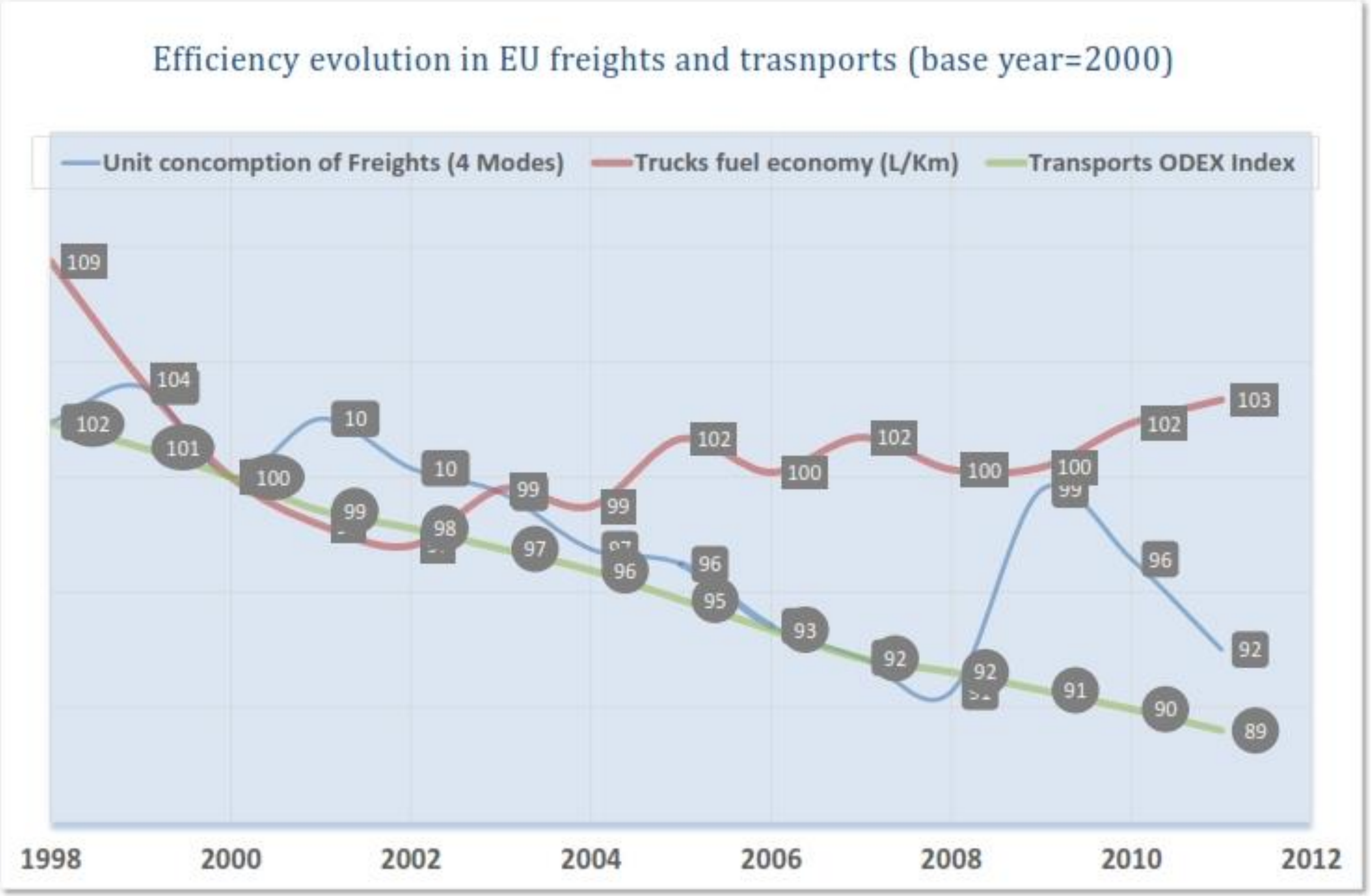
According to our estimations, cross-borders freights, between 1998 and 2011, amounted for about half of global freights across Europe. Nevertheless, BACI data comprises energy commodities, like trades of oil and gas, which are generally shipped across Europe by pipelines. Since efficiency of pipelines lies outside the scope of the present analysis, in what follows, freights will not include energy commodities



Efficiency evolution

The energy efficiency of transport in the EU improved by 15% between 1990 and 2010 (around 0.8%/year), as measured according to the ODEX indicator . Greater progress was achieved in the energy efficiency of both cars and airplanes than in the rest of the sector. Efficiency evolution of freights in EU is more uncertain, though, it generally improved.

It is shown the unit consumption (which is the inverse of efficiency, meaning that when it decreases, efficiency increases) of freights -4 modes, heavy-duty trucks compared to global efficiency of transports (ODEX index). Efficiency of freights generally improved, though little, since 1998. Energy efficiency in the road mode doesn't show a clear trend. Progress slowed down for trucks and light vehicles since 2005, with even a loss of efficiency since 2008.



The rebound effect theory states that a an increase in energy efficiency, reducing the cost of the related energy service, leads to an increase in service demand that may offset, partially or totally (0-100% rebound), the reduction in energy consumption per service unit delivered by the higher efficiency.

EVIDENCES FOR REBOUND EFFECT?.

Estimation of efficiency (elaboration on Enerdata)

Items :	**Unit consumption of road transport of goods**														
	ISO code	Unit	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Austria	AT	koe/ktkm	35	34	33	33	33	33	32	31	30	30	29	30	30	30
Belgium	BE	koe/ktkm	56	55	52	53	54	53	48	51	51	54	52	56	55	55
Bulgaria	BG	koe/ktkm	69	70	68	62	61	60	58	57	54	56	54	62	80	62
Croatia	HR	koe/ktkm	44	45	46	58	46	38	33	26	23	22	27	49	62	60
Cyprus	CY	koe/ktkm	192	196	203	206	197	187	232	179	213	211	185	235	206	231
Czech Rep.	CZ	koe/ktkm	20	21	21	22	22	25	27	31	28	30	29	33	28	27
Denmark	DK	koe/ktkm	25	25	24	26	24	24	23	22	23	24	23	22	25	25
Estonia	EE	koe/ktkm	26	25	23	24	20	22	20	20	18	21	21	24	21	19
Finland	FI	koe/ktkm	38	38	36	37	36	37	38	38	39	40	37	39	39	42
France	FR	koe/ktkm	55	54	53	54	54	54	54	55	54	53	52	57	58	57
Germany	DE	koe/ktkm	32	32	31	31	30	28	27	27	26	26	25	27	26	25
Greece	GR	koe/ktkm	86	83	85	82	81	81	70	81	89	109	96	117	99	131
Hungary	HU	koe/ktkm	29	36	36	38	40	36	33	29	29	29	29	29	27	27
Ireland	IE	koe/ktkm	63	63	65	66	67	68	66	68	68	61	62	66	66	66
Italy	IT	koe/ktkm	50	56	56	58	59	67	63	60	67	71	69	70	66	81
Latvia	LV	koe/ktkm	17	18	19	20	18	16	16	15	16	16	15	15	16	14
Lithuania	LT	koe/ktkm	28	33	31	34	30	27	26	25	23	22	21	27	24	21
Malta	MT	koe/ktkm	192	196	203	206	197	187	232	179	213	211	185	235	206	231
Netherland	NL	koe/ktkm	35	36	35	36	36	35	33	33	33	33	33	37	36	34
Norway	NO	koe/ktkm	28	32	26	27	26	31	31	35	32	32	31	31	30	29
Poland	PL	koe/ktkm	51	51	54	55	54	54	52	49	48	46	50	54	53	50
Portugal	PT	koe/ktkm	49	46	44	51	45	40	32	25	24	24	28	39	41	40
Romania	RO	koe/ktkm	20	21	19	19	19	22	24	29	26	30	29	33	26	26
Slovakia	SK	koe/ktkm	28	26	26	30	34	35	21	28	25	24	22	22	21	20
Slovenia	SI	koe/ktkm	47	48	47	46	49	49	50	50	51	49	49	49	48	45
Spain	ES	koe/ktkm	34	35	34	35	35	35	35	34	33	32	30	34	35	32
Sweden	SE	koe/ktkm	77	68	66	66	67	67	67	68	69	69	69	75	73	70
United King	GB	koe/ktkm	78	81	68	75	73	75	73	74	81	77	72	79	78	78
media			54	54	54	55	54	53	54	51	53	54	51	59	56	58

Correlation between efficiency and freights

Correlation were measure over the time sample spanning between 1998 and 2007, to avoid the crisis and the following drop in production/GDP. Once more, results are contradictory and of difficult interpretation. Correlation is generally positive, but of little significance in the case of road transports (if we state that the minimum level of significance is at least 70%, which is a reasonable minimum level, for a sample of 10 years data). For the case of freights (4 modes) the level of significance is generally high. In EU freights growth is positively correlated to efficiency increase, with a adequate level of significance (+97%), but cross-boarders freights seem negatively correlated to efficiency, though the level of significance is low (10%). According to this analysis is impossible to draw any certain, definitive conclusion about the correlation between energy efficiency and freights grow, though it seems to be generally positive. Is this a clue of a rebound effect in the European freights transport sector?

Efficiency and TKm, Pearson correlation index (1998-2007)			
	Freights (Odysee)	Cross-boarder (BACI)	Road freights (Odysee)
Austria	0,99	0,87	-0,71
Belgium	0,49	0,58	0,61
Bulgaria	0,95	0,84	0,46
Croatia	0,93	0,87	0,51
Cyprus	0,90	0,17	-0,35
Czech Rep.	-0,75	-0,77	0,73
Denmark	0,90	0,60	0,10
Estonia	0,87	-0,07	0,42
Finland	0,45	-0,56	0,68
France	0,84	0,44	0,96
Germany	0,96	0,23	0,49
Greece	0,80	-0,39	0,32
Hungary	0,75	0,72	0,12
Ireland	-0,34	-0,10	0,67
Italy	0,20	-0,87	-0,22
Latvia	0,79	0,55	0,49
Lithuania	0,91	0,91	0,42
Netherlands	0,86	-0,13	0,36
Poland	-0,63	0,04	0,28
Portugal	0,69	-0,36	0,51
Romania	0,98	-0,54	-0,39
Slovakia	-0,86	0,73	-0,11
Slovenia	0,46	-0,65	0,25
Spain	-0,43	0,38	0,45
Sweden	0,83	-0,76	0,75
United Kingdom	0,05	0,60	-0,47
Norway	-0,23	0,02	0,27
EU	0,97	-0,10	0,52

No clear trend: elasticity estimations are ambigous

A broader, albeit simple definition of rebound effect refers to the concept of service/efficiency elasticity (Galvin, 2014). This definition escapes any assumption about behaviors, preferences and costs structures in the economy and it only regards rebound effect as the elasticity between energy service (S) and energy elasticity (ε):

$R\_ε (S)=(∂S⁄S)/(∂ε⁄ε)$

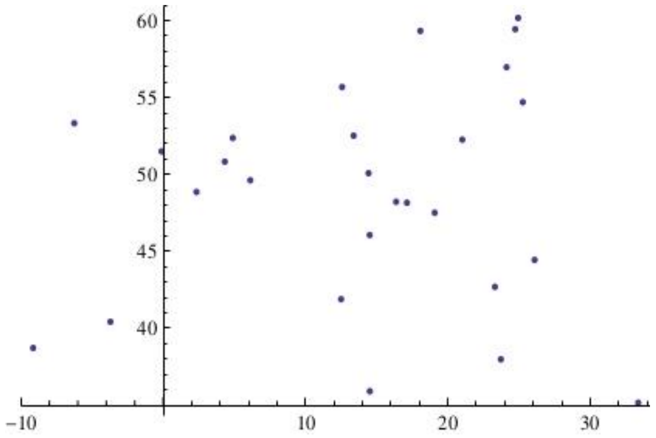
We regressed the yearly change in both energy efficiency and TKm and selected only those with a significance level (R2) above 0.5 for both the regressions (Table 3). Most of European countries lie beneath the level of significance of 0.5 R2, which is a very loose and optimistic level of significance to regress a trend in a sample of 10 data. That is to say that, for the majority of cases, either efficiency or energy service –or both, fails to exhibit a clear trend in time, making elasticity assessment uncertain and of little significance.

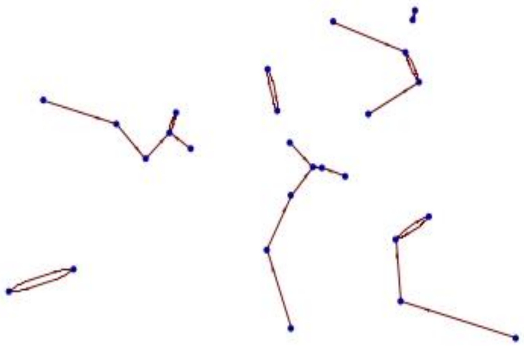
Rebound effect - % (1998-2007)			
	Freights (Odysee)	Cross-boarder (BACI)	Road freights (Odysee)
Austria	37,0	31,4	--
Belgium	--	--	--
Bulgaria	6,5	--	--
Croatia	35,1	-8,4	--
Cyprus	--	--	--
Czech Rep.	-166,1	-69,1	--
Denmark	48,5	74,0	--
Estonia	33,6	--	--
Finland	--	--	--
France	--	--	21,4
Germany	77,4	--	--
Greece	--	--	--
Hungary	--	--	--
Ireland	--	--	--
Italy	--	-89,5	--
Latvia	--	--	1,76
Lithuania	25,3	45,8	--
Malta	--	--	--
Netherlands	61,0	--	--
Poland	--	--	--
Portugal	--	--	--
Romania	76,34	--	--
Slovakia	--	--	--
Slovenia	--	--	--
Spain	--	--	--
Sweden	--	--	14,5
United Kingdom	--	--	--
Norway	--	--	--
EU	40,4	38,1	6,2*

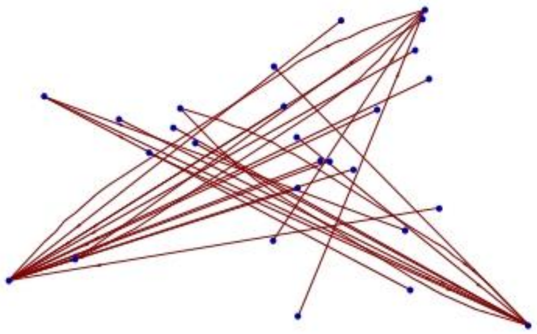
Are distances more or less biding for trades (thus, for mass flows)? Mass flows occur in a network -the productive system-, which is bound to topological and geographical constrains: both neighbors and «hubs» are priviledged in trades. Thus, we need a measure to evaluate to what extent the network is affected by distances in distribuing flows within itself.

EFFICIENCY REDUCES DISTANCES.

Network embedding and space filling





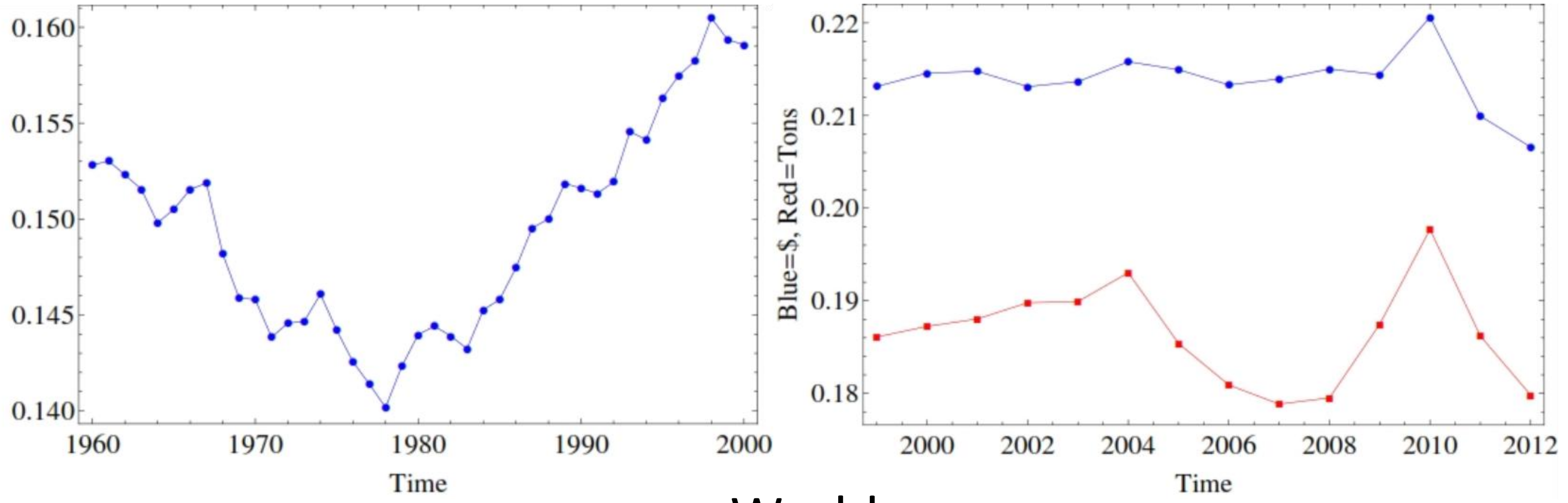


Spatial filling: EU28 vs World

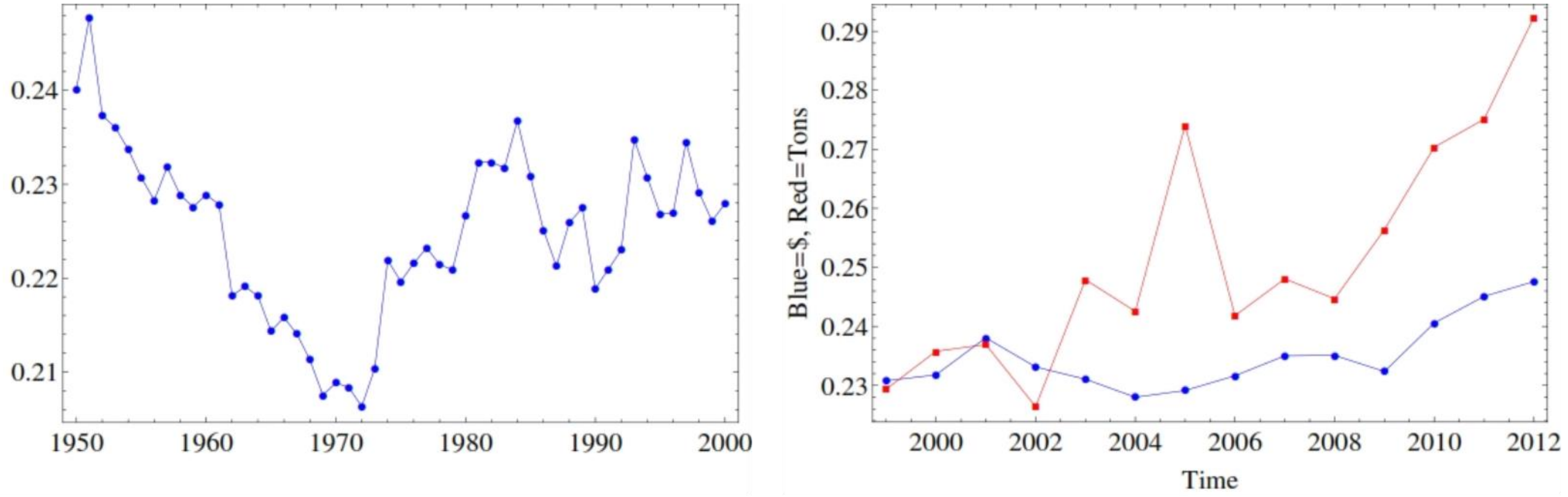
This measure, named spatial filling, assesses, on a normalized scale (0-1), the extent a network is stretched in the embedding space. That is to say, to what degree a network fills the space in which is entrenched.

$$\text{Filling}=\frac{\sum_{i=1}\sum_{i\neq j} d_{ij}w_{ij}-d_{Min}W_{tot}}{d_{Max}W_{tot}-d_{Min}W_{tot}}$$

If distances become more constraining, we expect the network to shrunk and filling to score a lower value. Figures on the right show the trend in the filling measured for the EU and World respectively, for the years 1960-2000, in monetary units (Gledistch database) and for the years 1998-2011 in both mass and monetary units (BACI database).



World



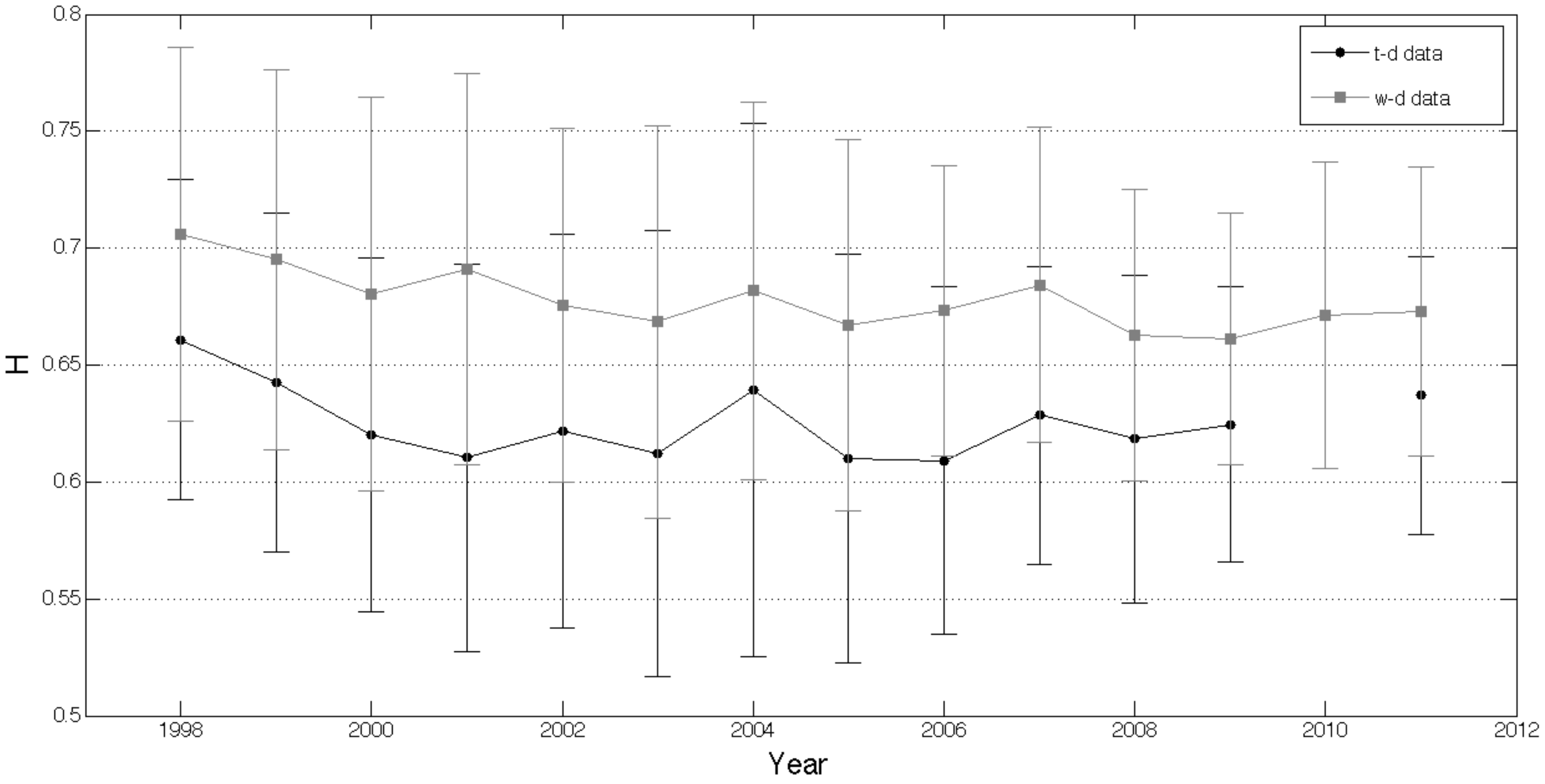
Europe

F. Ruzzenenti, F. Picciolo, D. Garlaschelli and R. Basosi. Spatial effects in real networks: measures, null models, and applications. PHYSICAL REVIEW E 86, 066110 (2012).

Mass lighter than money: new *distance puzzle?*

Hurst: it measures the randomness of a signal, the closer to 0.5, the more is random

According to Hurst in the WTW volumes in Tons are less constrained by distances than volumes in money!



We can order the flows according to the distance and measure H. The flows in mass (black) are closer to 0.5 than the flows in money: are less bound to distances.

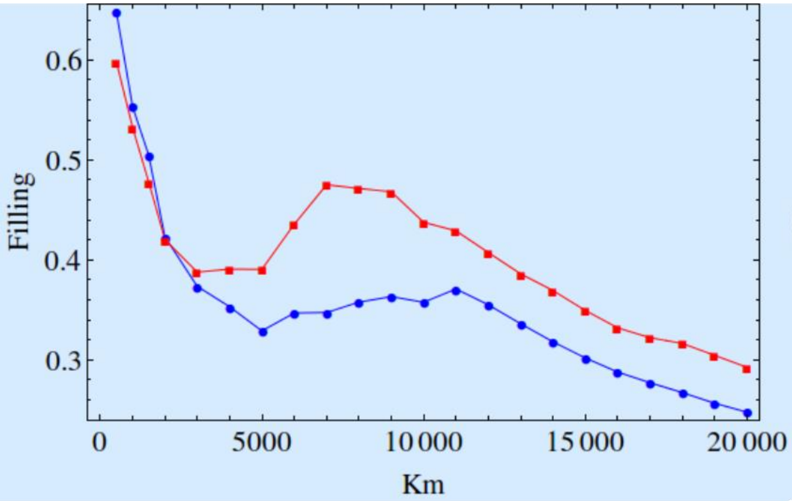
Space filling of several spatial netwroks: contradictory results

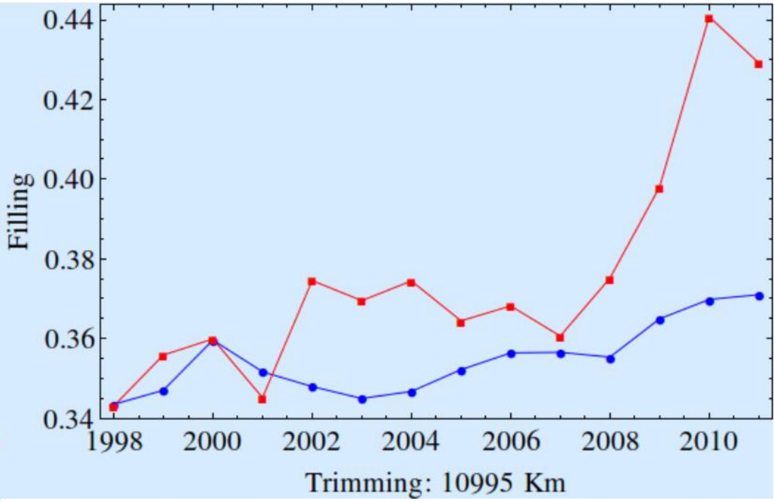
1998-2011	Filling ($)	Filling (ton)	Mean Distance and Diameter (Km)	Average Value ($)	Average Mass (ton)
Europe	0.214	**0.185**	748.6 (3766.3)	2.8*10^6	2.1*10^6
World	**0.234**	0.251	5007.8 (19904)	2.0*10^5	2.6*10^5
OECD	*0.163*	*0.161*	*3219.3 (19586.)*	*4.3*10^6*	*3.1*10^6*
Africa	**0.242**	0.265	2576.6 (9677.8)	1.4*10^5	4.0*10^5.
South America	0.289	**0.298**	2236.3 (6987.)	4.1*10^5	5.8*10^5.
East Asia Summit	**0.261**	0.402	5325.0 (12761.)	5.9*10^6	9.8*10^6
Ex-USSR	**0.287**	0.360	1534.1 (3950.1)	3.9*10^5	4.3*10^5

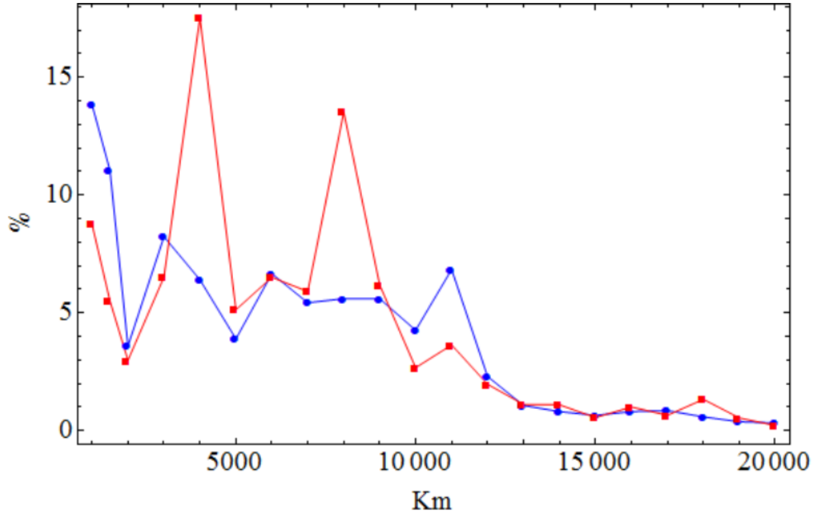
Filling of trimmed distances: World Trade Web

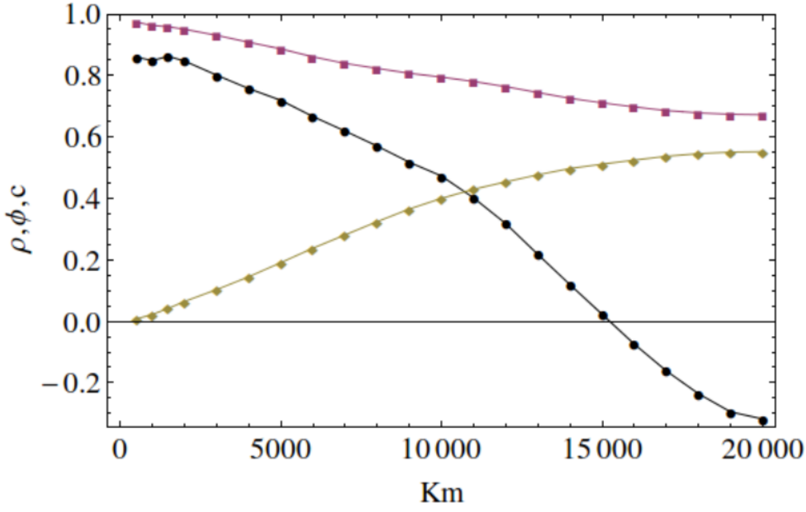
Hence, in order to test the dependence of spatial networks to the physical diameter (maximum distance), we trimmed (remove the links between nodes set at a distance greater than e certain threshold) the World Trade Web (WTW) starting for 500 km up to 19904.

We show (blue box) the curves of the filling at different trimmed distances of WTW for money (Blue) and mass (Red), for the year 2011. Interestingly, the two curves diverge at around 3000 km and converge at a level above 10.000 Km. In between these two thresholds, the red curve is remarkably higher than the blue curve, indicating that money is less spatially embedded than matter. This pattern varies in time, sometimes, after the second threshold the two curves overlap. In the second figure of the blue box, we show the trend in time of the second threshold, (which after a more refined measurement turns out to be 10.995 km).









Disentangling toplogicla effects and spatial effects: null models

A procedure recently developed for disentangling topology and spatial embedding consists in incorporating in our measure of the spatial filling a null model addressing the topology of the network:

$$\varphi_{NM} \equiv \frac{f - \langle f \rangle_{NM}}{1 - \langle f \rangle_{NM}}$$

φ is thereby an improved measure of the spatial filing of the network as it filters out the topological effects from the spatial effects. φ is a normalized measure, but, differently from the filling, varies from -1 to 1 and scores 0 when the spatial filling of the network is entirely explain by its topology .

$$\langle f \rangle_{NM} = \frac{\sum_{i=1}^{N} \sum_{j \neq i} p_{ij}^{NM} d_{ij} - F_{min}}{F_{max} - F_{min}}$$

Three null models (NM):

$$H^{DWCM}(G|\theta) = \sum_i (\alpha_i \overrightarrow{s_i} + \beta_i \overleftarrow{s_i})$$

$$H^{RWCM}(G|\theta) = \sum_i (\alpha_i \overrightarrow{s_i} + \beta_i \overleftarrow{s_i} + \gamma_i \overleftrightarrow{s_i})$$

$$w_{ij} = \frac{s_i^{\text{out}}}{1 - \frac{s_i^{\text{in}}}{\sum_{ij} w_{ij}}} \frac{s_i^{\text{in}} s_j^{\text{in}}}{(s_i^{\text{in}} + S_{ij})(s_i^{\text{in}} + s_j^{\text{in}} + S_{ij})}.$$

Masucci P., Joan Serras, Anders Johansson, and Michael Batty. Gravity versus radiation models: On the importance of scale and heterogeneity in commuting flows. Phys. Rev. E 88, 022812 – Published 22 August 2013997.

"T. Squartini, F. Picciolo, F. Ruzzenenti and D. Garlaschelli, Reciprocity of weighted networks Sci. Rep. 3, 2729 (2013)".

Null models are informative

This table shows the estimated φ for the six spatial networks so far considered and the three NM above mentioned, averaged over the period 1998-2011. In the parenthesis are the R2 values of the estimations.

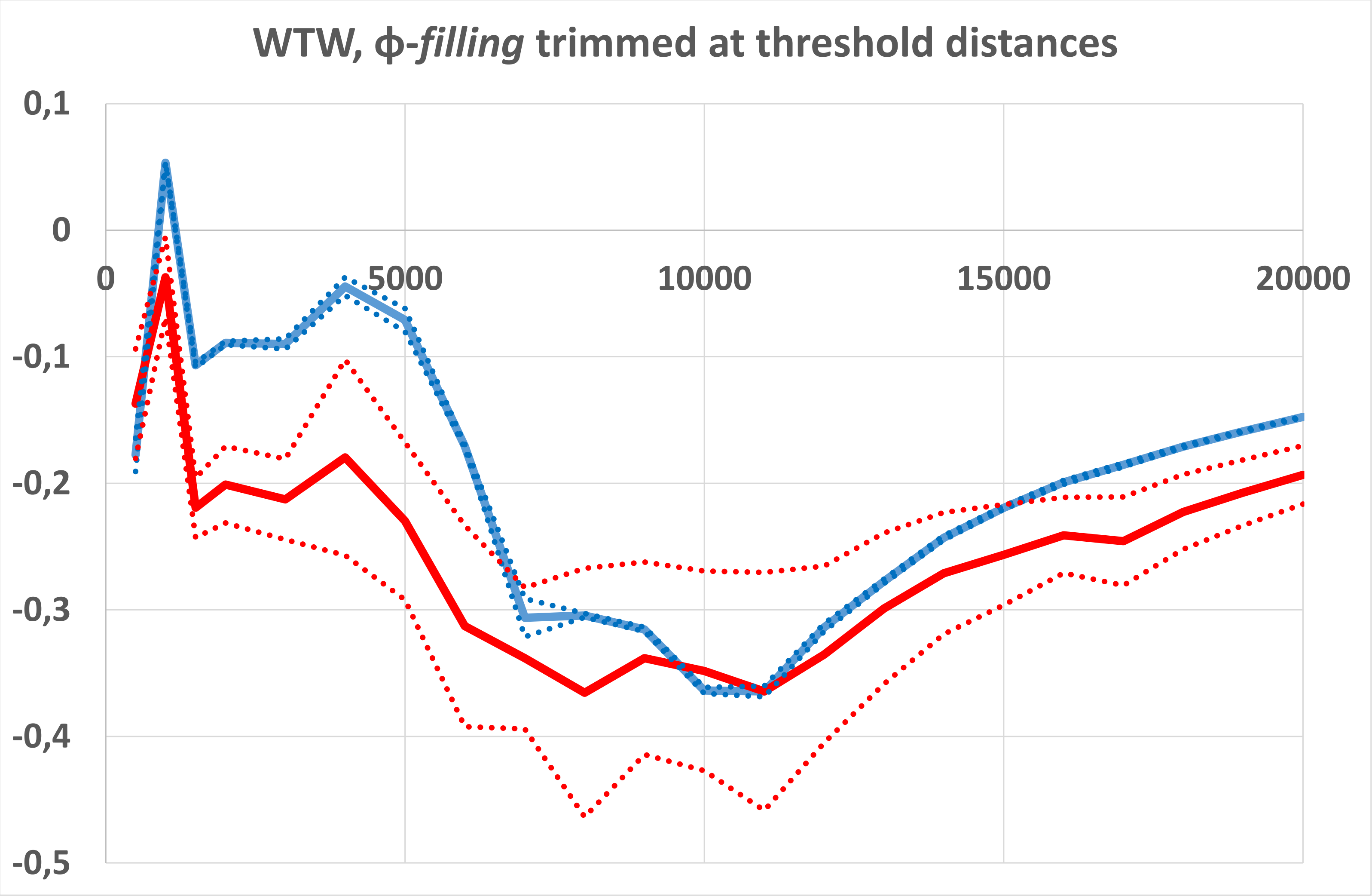
Interestingly, the implementation of the NM enabled us to shed a new light, altogether different, on the spatial embedding of the networks considered. A first result is that, according to the two ERG NM and consistently with previous analysis, all spatial networks are slightly shrunk -negative values of. Φ. This means that in all real networks, distance counts, although less than other topological properties, in determining trades.

A second major result is that the NM based on ERG reestablished the (expected) hierarchy among networks: Europe is the less embedded network and Africa is the most. The DWCM reestablishes also the (expected) equilibrium between mass and money.

	Φ ($): DWCM	Φ (Ton): DWCM	Φ ($): RWCM	Φ (Ton): RWCM	Φ ($): Radiation	Φ (ton): Radiation
Europe	-0.042 (0.76)	**-0.063** (0.65)	-0.043 (0.79)	**-0.059** (0.68)	0.105 (0.49)	**0.093** (0.25)
World	-0.147	**-0.197**	--	--	**--**	**--**
OECD	*-0.100*	***-0.219***	*-0.100*	***-0.191***	*0.081(0.47)*	*0.082(0.16)*
Africa	-0.20 (0.40)	--	-0.26 (0.50)	**-0.31** (0.16)	**0.113** (0.04)	0.118
South America	**-0.118** (0.87)	-0.073 (0.69)	**-0.122** (0.91)	-0.061 (0.83)	0.041 (0.19)	**0.06** (0.15)
East Asia Summit	0.015 (0.69)	***-0.103*** (0.78)	-0.031 (0.91)	**-0.148** (0.85)	**0.13** (0.61)	0.31(0.03)
Ex-USSR	-0.035 (0.89)	**-0.073** (0.60)	**-0.074** (0.91)	-0.053 (0.87)	**0.162** (0.45)	0.264 (0.20)

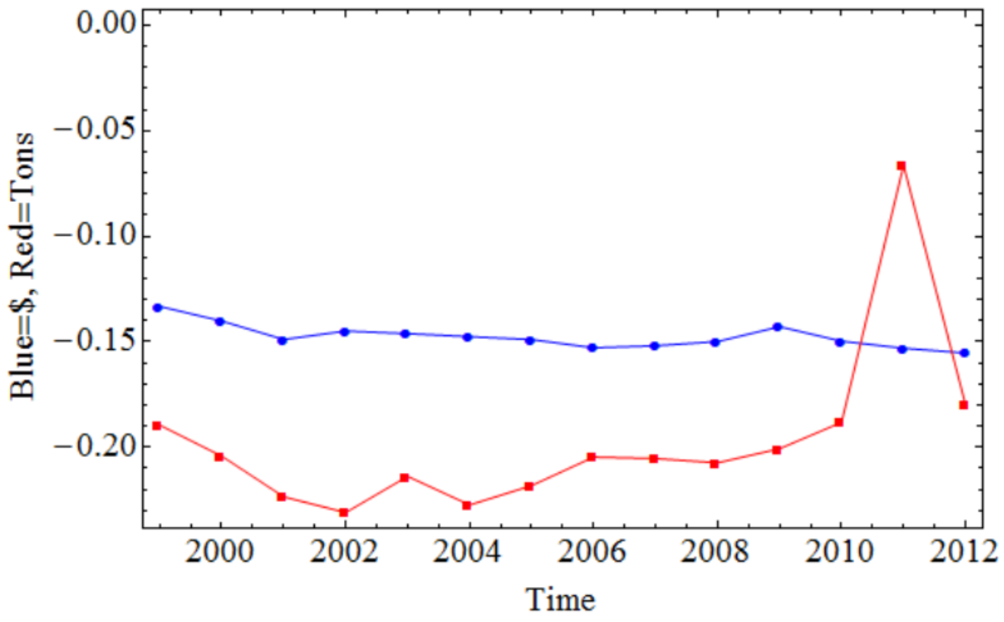
Spatial ϕ(DWCM) : trimmed at several distances

In this Figure we show the φ(DWCM) for the WTW trimmed over 25 distances, from 500 km the maximal distance of 19974, in both mass and monetary units and averaged over the period 1998-2011. In figure 11 the blue dots are generally above the red dots, singling that the network in mass units is almost always more embedded than the network in monetary units. However, there is still a narrow range in which the very contrary is true: between 9000 and 11000 km. In this range, apparently, trades in mass are less constrained to distances than trade in money. It is also worth noting that, that above this threshold the two curves revert their trend.

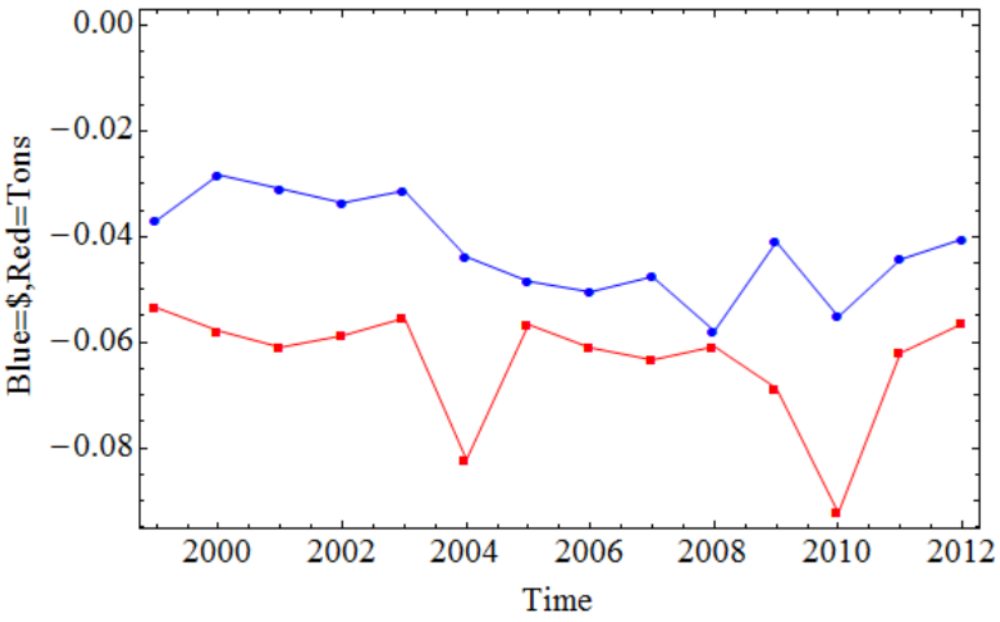


Blue=Money, Red=Mass

The role of distances in EU slightly increased: no Rebound Effect.



World



Europe

Thanks

Franco Ruzzenenti and Riccardo Basosi