Freight transport and economic growth : an empirical explanation of the coupling in the EU using panel data

Julien Brunel

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BRUNEL Julien, Transport Economics Laboratory (UMR-CNRS 5593), Univeristy Lumière Lyon 2, France.

Abstract: The link between transport and economic growth is nowadays understood behind the so-called issue of coupling. Transport intensity or transport elasticity to economic production are generally used to assess the link. In this paper, road freight intensity is decomposed into four factors. A European panel data estimation of these four factors isolates levels of coupling and levels of decoupling. We observe two factors of coupling (i. e. the rise of the average distance of transport and the increasing market share of road transport) and two factors of decoupling (the decreasing share of the industry in the economic production and the decreasing weight of industrial production).

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Contact : julien.brunel@let.ish-lyon.cnrs.fr

Introduction

The link between transport and economic growth has always been an issue for transport economists. The literature was originally interested to know the contribution of transport infrastructures to economic growth. The seminal paper of Fogel (1962) shows that rail transport was a source of the American surge at the end of the nineteenth century. Later, the development of endogenous growth models gave up a new insight to this issue like in Aschauer's paper (1989).

Another set of papers has emphasised the link between transport and economic growth in order to forecast transport demand. Most of these papers estimates transport or traffic elasticities to economic production. This literature corroborates the idea of a strong relation between transport and economic growth. Recently, a growing concern for environmental matters have changed the regard on this relation.

Experts of the Intergovernmental Panel on Climate Change (IPCC) assume in their third report that the global average surface temperature has increases by 0.6°C during the twentieth century (IPCC, 2001). This report also underlines the growing concentration of Greenhouse Gazes (GHG) due to human activity and forecasts a global warming comprised between two and six degrees Celsius for the twenty-first century. One can observe that transport sector plays a great role in global warming. For instance, French data form CITEPA (2005) shows that transports generate 28% of total CO_2 emissions in 2003. This share is higher than industries or residential and service activities ones since these sectors are respectively responsible of 21 and 22% of CO_2 emissions. Another matter of concern for CO_2 emissions caused by transportation is its high level of growth. From 1960 to 2003, its volume increased by more than 500% in France. This statement is true for other developed countries (Schäfer, 2005).

The growing concern for global warming has given a new sense to the link between transport and the economic growth. Nowadays, this issue is not only devoted to determine the role of economic growth in transport growth but it is also considering if this link between transport and economic growth can be broken. This issue, also called the coupling, has been an extensive issue for the literature. It has even been an issue for institutional literature. It was for instance the focus of a report of the *Standing Advisory Committee on Trunk Road*

Assessment (SACTRA, 1999) in the United Kingdom. European research programs were fulfilled on this topic like REDEFINE (1999) or SPRITE (2000). The European Conference of Ministers of Transports also organized a conference on this matter (ECMT, 2002). This issue is astonishingly even discussed in political documents like the European *White Paper* on transport policy (European Commission, 2001) in which the European Commission supports a decoupling strategy.

In the first section of this article, the main directions of the literature are reviewed. Then, this paper purposed an original assessment of the coupling using panel data econometrics. The second section of the paper presents a decomposition of the coupling in four factors. The third section estimates the four factors evolutions along with national income level using a European panel data sample. The fourth section interprets these evolutions in term of elasticity. It gives two factors of coupling (the average distance of transport and the modal split of transport) and two factors of decoupling (the share of the industry in the economy and the average density in value of the industrial production). Section five finally concludes.

The literature

The link between transport and the economy has been the object of a huge literature. This section presents the two main directions of this literature. The first direction deals with the assessment of the aggregate transport demand sensibility to economic production. Elasticity estimations are one of the most commonly used tool to assess this kind of relation. For instance, Meersman and Van de Voorde (1999) estimates the elasticity of freight transport to the industrial production in Belgium using an Error Correction Model. In France, Gabella-Latreille (1997) estimates national transport demand elasticity to the industrial production. More recently, this relation has been estimated using the cointegration (Meyer, 1998 ; Lenormand, 2002). It is also the issue of a paper of Kulshreshtha and Nag (2000) where a cointegrating VAR model is estimated for inter-urban railway passenger transports in India. For freight transport, Kulshreshtha et al. (2001) also uses the cointegration to estimate the relationship between economic growth and railway transport in India. Yao (2005) realizes a Granger causality test for the relation between transport and the production or firms inventory. It shows significant feedback effects between these variables. Elsewhere, Lahiri and Yao (2004) observe that transport activity related indexes are strongly synchronized with NBER-defined economic cycles.

Another mean to assess the link between aggregate transport demand and economic production is the *transport intensity*. This index is the ratio between transport demand (i. e. tons-miles or tons-kilometers for freight demand) and the value of the GDP. It represents the numbers of transport units necessary to produce one dollar or one euro of GDP. This aggregate indicator has been used by Baum (2000) and Baum and Kurte (2002). These papers conclude in a decreasing trend for transport intensity in Germany. They however observe that transport intensity is increasing if it only takes into account road transports and the industrial production.

The aggregate approach gives several estimations of the sensibility of transport demand to the economic production. However, these papers do not provide any explanation of the phenomenon. Explanations are given by a second a set of papers. The main purpose of this second set of papers is to decompose the aggregate transport demand in different levels of coupling or decoupling.

This methodology was initially developed by energy economics. Ang and Zhang (2000) offers a comprehensive review of these papers. Different kinds of decompositions are purposed to adapt it to transport economics. Kwon (2005) adapts the IPAT identity to the transportation sector. This identity is suggested by the simple equation $Impact = Population \times Affluence \times Technology$ that Kwon (2005) transforms for the transportation sector in

$$C = P \cdot \left(D/P \right) \cdot \left(C/D \right) \tag{1}$$

where C is the level of CO_2 emissions from car travels and D total car driving distance in vehicle-km. According the equation (1), the amount of CO_2 emissions produced by the transport sector is equal to a product of three factors. The first one (P) is the population. The second factor $\left(D/P \right)$ represents the car travel distance per person. It is also the affluence factor of the IPAT equation. Finally, the technology factor is given by the third factor $\left(C/D \right)$ that represents the amount of CO_2 emissions by unit of car traffic. An empirical estimation of equation (1) factors for Great-Britain between 1970 and 2000 shows that the better fuel efficiency of cars is offset by larger distances of travel.

Kiang and Shipper (1996) or Schipper, Scholl and Price (1997) decompose a transport energy use index into three factors. They are the activity (volume of transport realized), the structure of the activity (the modal share) and the intensity (energy used per loaded transport activity). These papers show the limits of technological improvements of the transport energy efficiency because such gains were until now always offset by an increasing volume of transport or a rise of road modal share.

In the transportation field, some papers leave the energy efficiency and focus on the link between transport activity and the economic growth. For instance, Redefine (1999) decomposes the link between transport and the economic growth into seven relations that are different levels of coupling or decoupling. In the same vain, a paper of Joignaux and Verny (2003) explains that the coupling between freight transport and the economy is mainly explained by the growing distance of transport in France. McKinnon and Woodburn (1996) insist on the impact of logistical decisions such as warehousing to explain the link between transport and the economy. Fosgerau and Kveiborg (2004) or Kveiborg and Fosgerau (2004) analyses Danish historical trends of several coupling factors. Steer Davies Gleaves (2003) offers such a description for a set of European countries.

This kind of papers affords some explanations of the coupling thanks to a decomposition of this issue in a set of factors. It shows some factors of coupling like the increasing distance of transport and some other factors of decoupling like the density in value of the production or the average load factor of trucks. In this paper, a decomposition is also purposed as one can see in the following section.

The model

Transport intensity is often used to assess the coupling in transportation economics (Baum, 2000). This index of coupling is inspired by the energy intensity, a common indicator in energy economics (Martin, 1988). Transport intensity is by definition the ratio between the number of tons-kilometers realized in a country and the value of the GDP of this country or

$$TI_i = \frac{TK_i}{GDP_i} \tag{2}$$

where TI_i is the transport intensity, TK_i is the number of tons-kilometers made in country i and GDP_i is the value of the GDP of the country i in dollars or in euros. Transport intensity represents the number of transport units (ton-kilometers) necessary to produce one unit of GDP (one euro or one dollar). If transport intensity increases or is constant, it corresponds to a case of coupling. In the opposite, a case of a decreasing transport intensity corresponds to a situation of decoupling.

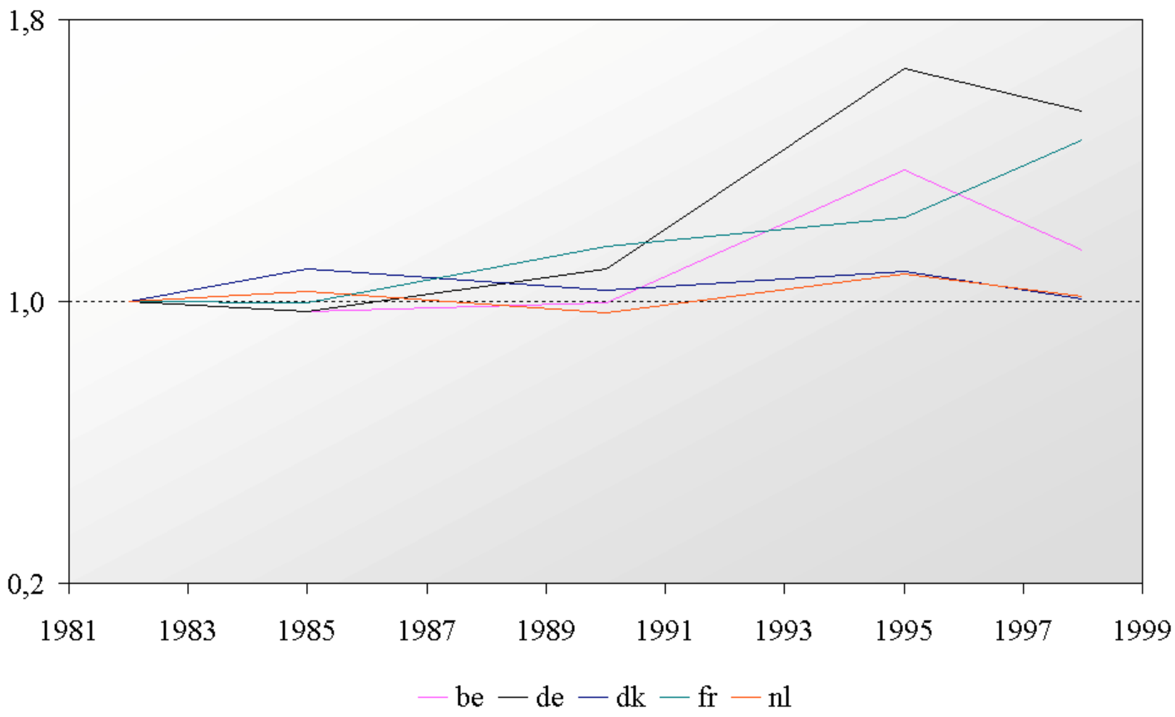
Other units can be used rather than the global number of ton-kilometers for the assessment of the coupling. It was precisely the focus of Stead (2001) in which a variety of indicators is discussed. The use of the volume of CO_2 emissions caused by transport gives the CO_2 intensity of transports. One can also distinguish between freight and passenger transport. The freight transport intensity is the number of ton-kilometers made by freight vehicles necessary to produce one unit of GDP. As road transport is the main source of CO_2 emissions, it is then better to assess a *road freight intensity* (noticed RFI_i) given by

$$RFI_i = \frac{road\_TK_i}{GDP_i} \tag{3}$$

where $road\_TK_i$ is the number of ton-kilometers made by road freight vehicles in the country i. The use of the vehicle-kilometers would even be better because the vehicle is the source of pollution. Vehicle-kilometer is nevertheless a variable quite difficult to find in international statistical database. It is why the road freight intensity is used rather than the road traffic intensity.

Figure 1 represents the evolution of RFI_i for a European panel of countries from 1982-1998. It shows that the road freight intensity is increasing or constant for this sample. It then says that these countries are cases of coupling.

Figure 1 Evolution of RFI_i for a European panel of countries (Eurostat, 2002 ; PWT, 2002).



Following the equation (3), the road freight intensity is decomposed into a product of four ratios giving the following identity

$$RFI_i = \frac{road\_TK_i}{TK_i} \cdot \frac{TK_i}{T_i} \cdot \frac{T_i}{IND_i} \cdot \frac{IND_i}{GDP_i} \tag{4}$$

where TK_i is the number of ton-kilometers made by freight transport in country i whatever the mode of transport, IND_i the industrial production of the country i and T_i the number of transported tons. Therefore, according to equation (4), RFI_i is a product of four factors. These factors are the followings.

- The first factor is the ratio between the number of tons-kilometers of freight made by road in a given country and the number of tons-kilometers made in the same country by all modes of freight transport. It is the modal share of road transport.

- The second factor corresponds to the number of transported tons in a country by unit of industrial production. It could be interpreted as the average weight of one unit of industrial production or as the inverse of the density in value of the industrial production.

- The third factor corresponds to the average distance made by a transported ton whatever its mode of transport.

- The fourth factor is equal to the ratio between the industrial production and the GDP of a country. It is the share of the industry in the economy.

Equation (4) then yields

$$\left[\begin{array}{c}\text{Raod}\\ \text{freight}\\ \text{intensity}\end{array}\right]=\left[\begin{array}{c}\text{Road}\\ \text{modal}\\ \text{share}\end{array}\right]\cdot\left[\begin{array}{c}\text{Average}\\ \text{distance}\end{array}\right]\cdot\left[\begin{array}{c}\text{Average}\\ \text{weight of \$1 of}\\ \text{industrial}\\ \text{production}\end{array}\right]\cdot\left[\begin{array}{c}\text{Share of}\\ \text{the}\\ \text{industry in}\\ \text{GDP}\end{array}\right] \quad (5)$$

Road freight intensity was decomposed into a product of four factors. These factors are different levels of coupling or decoupling. The following section then investigates the evolution of these four factors.

Estimation

This section estimates the evolution of these four factors along with the level of national income. In the first sub-section, the model specification is presented. Next, a second sub-section provides the results of econometric estimations.

Model specification

The empirical estimation of the model is inspired by previous papers on environmental economics made upon the link between pollutes and the economic growth. This set of papers concludes in the existence of an inverted-U shape curve between pollution and the economic income (Holtz-Eakin and Selden, 1992 ; Shafik, 1994 ; Grossman and Krueger, 1995). This curve is also called the Environmental Kuznets Curve (EKC).

In the current case, this paper estimates the relation between national level of economic income and the four factors of coupling defined above. A quadratic model specification is estimated. This model specification is similar to Shafik (1994) or Holtz-Eakin and Selden (1992). Estimated models are then the followings.

$$msh_{it} = \alpha_{msh} + \beta_{msh} \cdot y_{it} + \gamma_{msh} \cdot ysq_{it} + \varepsilon_{it} \quad (6)$$

$$dst_{it} = \alpha_{dst} + \beta_{dst} \cdot y_{it} + \gamma_{dst} \cdot ysq_{it} + \varepsilon_{it} \tag{7}$$

$$wgh_{it} = \alpha_{wgh} + \beta_{wgh} \cdot y_{it} + \gamma_{wgh} \cdot ysq_{it} + \varepsilon_{it} \tag{8}$$

$$ind_{it} = \alpha_{ind} + \beta_{ind} \cdot y_{it} + \gamma_{ind} \cdot ysq_{it} + \varepsilon_{it} \tag{9}$$

where msh_{it} is the logarithm of the road modal share, wgh_{it} the logarithm of the average weight of the industrial production, dst_{it} the logarithm of the average distance of transport, ind_{it} the logarithm of the share of the industry in the GDP, y_{it} the per capita income taken in logarithm and ysq_{it} the square of the logarithm of the per capita income.

The data set is detailed in the appendix. For (6), (7) and (8), the sample is composed by the fifteen older European Union member countries from 1982 to 1998. Model (9) also uses a panel data sample but it has been enlarged to all OECD member countries and the 1970-2000 period.

The panel nature of the sample implies peculiar econometric estimations. Two model estimations are performed. The first one is a *Fixed Effect Model* (FEM) estimation. This model introduces an individual country-specific constant term. The second one is a *Random Effect Model* (REM) estimation. In this model, the error-term is assumed to be the sum of two elements

$$\varepsilon_{it} = \mu_i + \lambda_{it}$$

where the first term is a country-specific error-term and the second term a white-noise. It is estimated by feasible, two steps generalized least squares (GLS). Two statistics are then computed to assess these models. The first one is the Breusch and Pagan's Lagrange multiplier statistic to test the presence of individual specific-effects. This statistic follows a γ^2 law at one degree of freedom. The null-hypothesis of no-specific-effect is rejected when this statistic is superior to 3.84 (at 95% level). The second statistic is the Hausman statistic to test REM against FEM. The Hausman statistic (H) also follows γ^2 law at *k-1* degrees of freedom with *k* the number of regressors. High values of H argues in favor of FEM. In the following subsection, the results of the two previous tests are presented. Then, FEM or REM estimations results are given.

Results

The results of both LM and Hausman tests figure in table 1. The Lagrangian Multiplier test shows that the four models present country-specific effects. It then argues in favor of a FEM or a REM rather than for a classical regression without group dummies. Furthermore, the Hausman test reveals that a fixed-effects model is more significant than a random-effect model for all the models except for model (9). The share of the industry among the GDP is the only model where a random effect model is estimated.

Table 1 LM and Hausman Tests

	LM-Test		Hausman Test	
	LM-stat.	Prob.	H-stat.	Prob.
model (6) (modal split)	542.10	.00	14.15	.00
model (7) (average distance)	62.89	.00	8.57	.01
model (8) (average weight)	14.86	.00	9.62	.01
model (9) (industry share)	8484.98	.00	1.40	.50

The following table presents the results of the fixed effect models estimations of models (6) to (8). The results are statistically significant. Standard-errors of the estimated parameters are always significant. The Fisher statistic and the correlation coefficient also shows significant values.

Table 2 FEM estimations (standard-errors in parentheses)

Variables	modal split	average weight	average distance
y_{it}	-5.28	-78.09	35.63
	(1.50)	(21.56)	(15.61)
ysq_{it}	.28	3.95	-1.77
	(.08)	(1.10)	(.80)
F	58.29	6.20	10.73
R^2	.85	.41	.55
Sample size	169	149	160

A REM is estimated for model (8). Results figure in table 3. The estimation is also highly significant as one could observe with standard-errors. It confirms the correlation between the level of national income and the levels of coupling. The following subsection gives an interpretation of these regressions.

Table 3 REM estimations (standard-errors in parentheses)

Variables	industry share
y_{it}	5.76
	(.20)
ysq_{it}	-.30
	(.01)
Intercept	-28.95
	(.96)
Sample size	783

Interpretation

The results of above estimations are interpreted in term of elasticities. One can get the elasticity thanks to the derivative of the quadratic, estimated relation between economic income and the factors of coupling. It gives that

$$\xi_{it}^{n} = \hat{\beta}_n + \hat{\gamma}_n \cdot y_{it} \tag{10}$$

where ξ_{it}^{n} is the estimated income-elasticity of the factor of coupling *n* and $\hat{\beta}_n$ and $\hat{\gamma}_n$ are the previously estimated parameters.

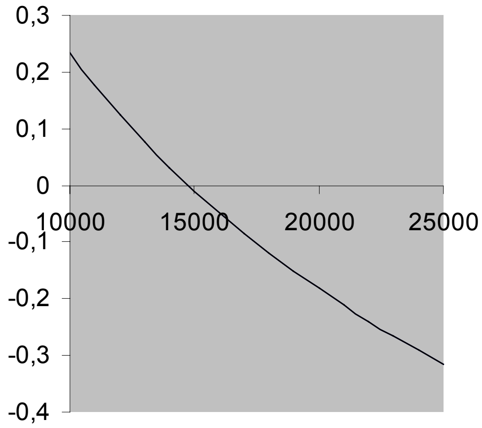
Figure 2 presents the income-elasticity of the four factors of coupling along with the level of national income. The first factor of coupling corresponds to the share of the industry in the GDP (variable ind_{it}). It first presents a positive, decreasing elasticity until the GDP per capita level of \$15,000. Then, the income-elasticity becomes negative. This graph illustrates a well-known phenomenon that was ever pointed by Kuznets (1955) in its paper on income inequalities. It shows that the industrial sector share among the GDP of a country draws an inverted-U shape along with the level of income. European Union countries are then in a situation where the industry accounts for a decreasing share of the GDP i. e. in a situation of negative income-elasticity of the industry share. It therefore corresponds to a level of decoupling.

For variable msh_{it}, figure 2 reveals a positive and slightly increasing income-elasticity. Negative values are observable for very low levels of income. One cannot interpret such values because they correspond to income levels that are not significant in the sample. The main point of the graph is the fact that the income-elasticity of road modal share is positive. It induces that a rise of national income level involves a rise of the road modal share. European industry has known crucial changes these last twenty years among them a structural modification of the production. Heavy goods productions such as coal or steel productions were often left for lighter industrial productions. This modification of the industrial production structure produced a structural effect over the modal split of the transport market because heavy products are more likely to be transported by rail than lighter products. Furthermore, the development of the Just-in-Time manufacturing organization induced a high demand for quick, reliable transports. At the same time, road transport experienced a liberalization of its industry. These two facts produce an increase of the road transport competitiveness in comparison to the railway alternative that is still a public monopolistic industry in a large majority of European countries. Structural changes of European industry and the worsening competitiveness of railway transport explains that the road-modal share factor is a level of coupling.

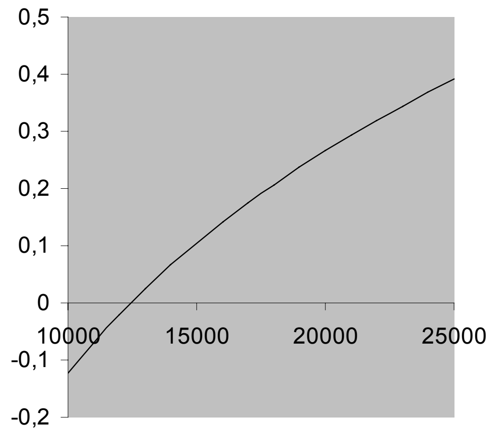
Figure 2 also represents the income-elasticity of the industrial production weight (variable wgh_{it}). One should first observe a negative and highly increasing income-elasticity. Then, the income-elasticity becomes positive since a level of per capita income of $20,000. The main point of this graph is the negative but increasing income-elasticity. It says that the average weight of the industrial production decreases along with the rise of the national income. This rise goes on until a progressive level of saturation where the average weight does not change anymore. Actually, the right-side of the graph is not very significant. One should get in mind that the most representative part of these graphs is roughly comprised between income values of $12,000 and $20,000. It is why the average weight of the industrial production has to be understood as a factor of decoupling. This factor has to be linked with the restructuration of European industry previously mentioned to explain changes of road modal share.

Figure 2 Estimated income-elasticities of the factors of coupling

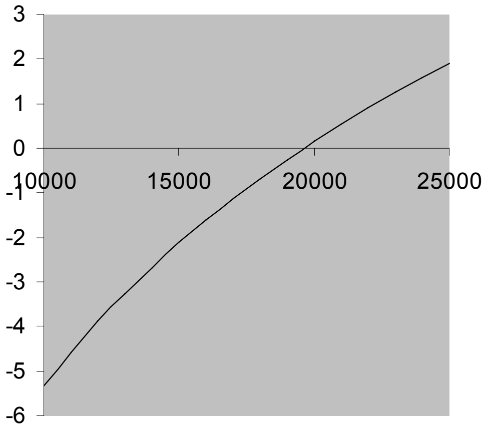
Variable: ind_{it}



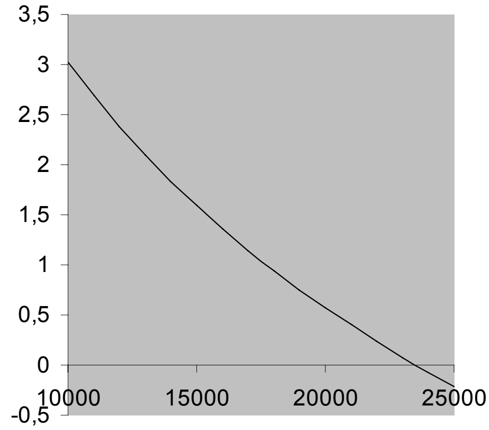
Variable: msh_{it}



Variable: wgh_{it}



Variable: dst_{it}



Finally, figure 2 represents the income-elasticity of the average distance of transport (variable dst_{it}). This figure points out a positive, decreasing income-elasticity. It states that the rise of the national income goes with an increase of the average distance of transport. Another point is that the income-elasticity is negative beyond the value of $23,000. It means that the average distance of transport reaches a maximum for the value of $23,000. Actually, one should first get in mind the low significance of income values after $20,000. Furthermore, one can interpret this phenomenon in term of geographic constraint. It does not mean that the average distance of transport will decrease beyond this value. The average distance of domestic transport does not grow anymore because it cannot grow anymore inside a national, physically constrained territory. The sample is made by the fifteen older European Union countries among which many small countries can be found. It is then not surprising to reach such a saturation point. Therefore, one should interpret the average distance as a factor of coupling. The inclusion of international transport in the analysis would even more clearly makes it as a factor of coupling.

The interpretation of these regressions reveals two levels of coupling and two levels of decoupling. Factors of coupling are the rise of the average distance of transport and the increasing modal share of the road in domestic transports. The two factors of decoupling are the decrease to the average weight of the industrial production and the decline of the industry share in the GDP.

Conclusion

This paper investigates the link between transport and the economic growth. Road freight transport intensity is decomposed into four levels of coupling. A European panel data estimation of this decomposition reveals two factors of coupling and two factors of decoupling. Factors of coupling are the increasing distance of transport and the growing modal share of road transport. Inversely, the declining share of the industry in the GDP and the decreasing weight of the industrial production are two factors of decoupling.

These conclusions are consistent with most of the results found in the literature. For instance, the rise of the average distance of transport has often been identified as an explanation of the coupling. The decreasing weight of the industry in the economy has also been observed in a many papers. Otherwise, this paper is consistent with the idea according which the elasticity of transport with respect to the economic production is not constant.

These results should however be completed by further works. One of these can be the inclusion of international transport in the analysis. It has ever been mentioned that the average distance of transport would certainly be a stronger factor of coupling. Another direction that future researches can follow is in the enlargement of this analysis to other contexts. This paper deals with European countries from 1982 to 1998. It should be interesting to apply this model to other countries from other continents to investigate the evolution of these factors. A temporal enlargement can also be useful and would certainly gives more consistent results.

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Appendix: The data set

The panel data sample is composed by economic data and by transport data. Transport data are given by Eurostat (2002) *NewCronos* database. More precisely, the variable $road\_TK_i$ is given by the table *B-Road Transport V3-09. National annual transport by distance class and type of carriage (Mio Tkm)*. It is composed by the fifteen older European Union member countries from 1982 to 1998. One should nevertheless remark several blanks. Data are only available since the country adhesion to the Union. Furthermore, some countries present several missing data. The railway variable is given by the table *A-Rail Transport V3-05. National annual transport by distance class and group of goods (1000 T, Mio Tkm).* The variable TK_{it} is given by the sum of the previous variables. The variable T_{it} is also given by the sum of road and rail transport series. The road transport series is presented in the *table B-Road Transport V3-08. National annual transport by distance class, type of carriage and group of goods (1000T)* whereas table *A-Rail Transport V3-05. National annual transport by distance class and group of goods (1000 T, Mio Tkm*) gives data for railways volume of transport. It the excludes from the analysis inland water-ways domestic transport even if this mode of transport is not insignificant for countries like Germany, Netherlands or Belgium. Its share is however declining in comparison with road transport. The analysis is not biased by inland-water ways transport omission: road modal share is a factor of coupling. Furthermore, in a majority of countries of the sample, this mode of transport is insignificant.

Economic data are given by other database. The share of the industry in the GDP is given by the OECD table *Annual National Accounts for OECD Member Countries - Data from 1970 onwards: GDP by output at constant prices* (OECD, 2004). OECD database presents several blanks. For instance, data for Switzerland or Ireland are always missing. Furthermore, data are not given before the adhesion to the organization. Finally, income data have been taken in Purchasing Power Parity (PPP). PPP income data are provided by the *Penn World Tables* of the Center for International Comparisons of the University of Pennsylvania. Actually, we use the latest version of this database or the PWT Version 6.1 (Heston, Summers and Aten, 2002). These data are taken for all OECD countries from 1970 to 2000.