Antecedents of the Physical Internet: A Cross-Country Analysis of Transportation Volume Change

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Abstract: *As the recent development of the Physical Internet contributes to a more efficient usage of transportation and logistics technologies, the question arises whether these technologies may have a varying impact on countries' economic performance. Thus, it is crucial to understand the drivers of transportation volume. In this paper we present a country-level analysis of the determinants of growth of transportation volume by employing data collected for 28 European countries for the 10-year period of 2004-2013 from two data sources: (1) Eurostat and (2) World Bank. We especially focus on two modes of transportation technologies: water transport and road transport. By highlighting the close relationship between country-specific factors and the growth of transport volume, we extend the general framework of the Physical Internet by explicitly taking factors into account which in most cases cannot be directly influenced by logistics decision makers. This research therefore integrates a macroeconomic perspective into the overall Physical Internet framework.*

Keywords: Physical Internet, Technology Diffusion, Transportation Technologies, Growth of Transportation

1 Introduction

The Physical Internet is defined as "a global logistics system based on the interconnection of logistics networks by a standardized set of collaboration protocols, modular containers and smart interfaces for increased efficiency and sustainability" (Ballot et al., 2014, p. 23). As the recent development of the Physical Internet contributes to a more efficient usage of transportation and logistics technologies (Montreuil, 2011), the question arises whether these technologies may have a varying impact on countries' economic performance. Thus, it is crucial to understand the drivers of transportation volume in the first place. Empirical research on relevant drivers and enablers is also needed, since previous research on the Physical Internet has been limited to a handful of simulations and case studies (Ballot et al., 2014). From the viewpoint of innovation diffusion a substantial body of research on technology diffusion exists (Comin and Hobijn, 2004; Comin and Nanda, 2014; Dewan et al., 2005; Pulkki-Brannstrom and Stoneman, 2013), but research on the diffusion of transportation technologies is still scant. To address this research gap on the combination of Physical Internet and innovation diffusion, we present a model in which we examine factors influencing countries' growth of transportation volumes. Specifically, we address the following research questions:

- Does a country's level of economic development and openness of economy impact the growth of transportation volume?
- What country-specific factors (other than economic development and openness of economy) influence the growth of transportation volume?
- Are there regional differences in the growth of transportation volume?

In order to answer these questions, we conduct a country-level analysis of the determinants of growth of transportation volume by employing data collected from 28 European countries for the 10 year period of 2004-2013 from two data sources: (1) Eurostat and (2) World Bank. We especially focus on two modes of transportation technologies: water transport and road transport. We also classify these countries into two groups: Western and Eastern European countries.

In the next section, we describe the literature on the diffusion of innovations, focusing on theories and models of technology adoption. Section 3 presents our data sources, research methods and the model. We present our results in section 4, followed by discussion and conclusions in section 5.

2 Literature review

Various theories and models of technology adoption exist, such as the diffusion model of innovation (Rogers, 1995) and the epidemic model of technology diffusion (Fagerberg et al., 2014). Roger's theory of diffusion posits that the growth pattern of adoption of a specific technology takes the form of a cumulative normal distribution, which is an S-curve. The theory focuses on the process by which innovation is communicated through certain channels over time among the members of a social system. The Gompertz and logistic curves are most widely used specifications of S-curves. The epidemic model of technology diffusion has been widely used in econometric studies of economic growth and technological change (Fagerberg, 1994) or technological change across countries (Fagerberg and Verspagen, 1996; Fagerberg et al., 1997).

Based on diffusion theories and models, previous research has considered a number of country-level factors influencing technology diffusion within a country (Comin and Hobijn, 2004; Dewan et al., 2005; Kiiski and Pohjola, 2001; Ganley et al. 2003; Pulkki-Brannstrom and Stoneman, 2013). From these theories and models, we consider human capital, openness of the economy, levels of economic development, technology use and infrastructure, and economy structure. The rate of adoption of a technology in its early stages is in large part determined by the level of economic development of a country. However, long run differences in adoption rates are for a much larger part determined by country specific factors that are not correlated with economic development (Comin and Hobijn, 2004). Which factors this might possibly be is part of the empirical analysis.

3 Methodology

3.1 Data sources and conceptual framework

In order to conduct a country-level analysis of the determinants of growth of transportation volume, we employ data collected for 28 European countries for the 10 year period of 2004-2013 from two data sources: (1) Eurostat and (2) World Bank. We focus on two modes of transportation technologies: water transport and road transport. As a measure for shipping technologies, we use container port traffic, which corresponds to the flow of containers in standard twenty-foot equivalent units (TEUs). As a measure of road transportation technologies, we use road freight transported in thousands of tonnes and tonne-kilometer (TKM). These measures serve as proxies of the intensity with which transportation technologies are used in a particular country. Figure 1 illustrates our analytical framework.

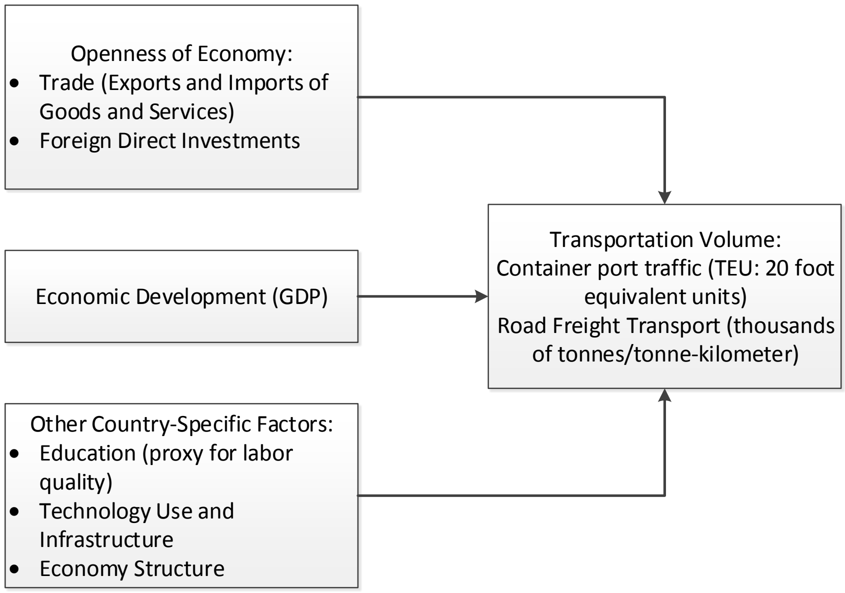

Figure 1. Antecedents of Transportation Volume

As shown in Figure 1, we hypothesize that economic development and openness of the economy as well as factors like education and technology influence the overall transport volume. The growth of transportation volume is influenced by a country's level of economic development. However, long run regional differences are more likely determined by country-specific factors (Comin and Hobijn, 2004). Openness of the economy often refers to free trade and inflows of foreign direct investments (FDIs). These factors might influence levels of transportation volume by facilitating production and trade of goods produced. The growth of transportation volume might also be driven by high-quality labor. The size of urban population might be related to levels of transportation volume because a greater demand for transportation of goods in urban areas exists. We also consider factors such as technology use and infrastructure, particularly telecommunications technologies, the Internet and telephone coverage. These technologies are considered as general purpose technologies (GPTs), and the level of diffusion of GPTs may influence the adoption of other technologies. The economic structure of national economies, such as the proportion of employment in the manufacturing and transportation industry can also influence transportation volume. Thus, we hypothesize that country-specific factors exist which account for regional differences.

3.2 Model

Our model is derived from an S-curve diffusion model, which assesses the effects of environmental factors on technology diffusion (or usage) across a body of countries. There are a few choices pertaining to the form of curve. Following previous research (Kiiski and Pohjola, 2001; Ganley et al., 2003), we employ the Gompertz model of diffusion, one of the most widely used forms of the curve. The Gompertz model follows an S-shaped path from the earliest moment of adoption to the point of saturation (Berndt et al., 2000). We use log-differencing to correct the simultaneity bias inherent in the model and also to minimize multicollinearity issues between explanatory variables (Ganley et al., 2003). Our analysis of the change in the growth rate of transportation technologies will discern deviations from the predicted S-curve, which indicate evidence of effects of country-specific factors. Our model is as follows:

$(\Delta \ln H_t/H_t - \Delta \ln H_{t-1}/H_{t-1}) = c + \beta \Delta \ln H_t + \gamma \Delta \ln Z_t$

$\Delta \ln H_t/H_t - \Delta \ln H_{t-1}/H_{t-1}$ represents the growth rate of the logarithms of technology diffusion (transportation technologies used in a country: container port traffic and road freight transport) taking the first difference. $\Delta \ln H_t$ represents the growth of technology diffusion as a logarithm. $\Delta \ln Z_t$ represents the deviation from the saturation level in the previous period and Z_t represents country-level factors as exogenous variables (e.g., GDP per capita, trade, tertiary school enrollment, urban population) which might affect the growth rate of technology diffusion. The process of deriving our model from the Gompertz model of diffusion is as follows (Ganley et al., 2003):

Gompertz Model: $dH_t/d_t = \beta(Ht(\ln H_t^* - \ln H_t))$

The left-hand variable is the growth of the logarithms of technology diffusion and the right-hand equation is the S-shape of the diffusion process. The generalized Gompertz model for the growth of the log-levels is:

$\ln H_t - \ln H_{t-1} = \beta(H_t(\ln H_t^* - \ln H_t)$ (1)

The saturation level of technology diffusion is:

$\ln H_t^* = \ln H_{t-1}^* + \gamma \Delta(\ln Z_t)$ (2)

where $\Delta(\ln Z_t)$ represents the deviations from the saturation level in the previous period (Z_t represents exogenous variables affecting the growth).

Thus, $\ln H_t^* - \ln H_{t-1}^* = \gamma \Delta(\ln Z_t)$ (3)

By dividing equation (1) by H_t and taking the first difference, we reach the following equation: $(\ln H_t - \ln H_{t-1})/H_t - (\ln H_{t-1} - \ln H_{t-2})/H_{t-1} = \beta[(\ln H_t^* - \ln H_t) - (\ln H_{t-1}^* - \ln H_{t-1})$ (4)

By inserting equation (3) into equation (4), we get the final general form of the equation:

$(\Delta \ln H_t/H_t - \Delta \ln H_{t-1}/H_{t-1}) = \beta D \ln H_t + \gamma \Delta(\ln Z_t)$ (5)

We include a constant in the model to account for the potential of systematic bias in countries' actual growth patterns:

$(\Delta \ln H_t/H_t - \Delta \ln H_{t-1}/H_{t-1}) = c + \beta \Delta \ln H_t + \gamma \Delta \ln Z_t$

We estimate the model by using ordinary least squares regression with robust (heteroscedasticity-consistent) standard errors. Tables 1a and 1b show the summary statistics of the full sample and the subsamples of Western and Eastern European countries. Figure 1 shows the development of TEU container usage.

Table 1a: Sample Statistics for Full Sample (2004-2013)

Variables	Full Sample		
	Mean	St. Dev.	N

TEU (in thousand)	3,929.0	4,953.0	211
Thousands of tonnes (road freight)	24,372.0	45,185.6	230
TKM, tonne-kilometer (road freight)	2,800.7	5,891.3	230
GDP per capita	34,187.5	23,795.2	280
FDIs (% of GDP)	6.9	14.8	280
Trade (% of GDP)	106.8	54.5	280
School enrollment, tertiary (% gross)	65.1	15.5	256
School enrollment, secondary (% gross)	103.7	10.6	269
% of individuals using the Internet	64.1	19.1	280
Employment manufacturing (% of total)	16.7	5.2	280
Employment trade, transport, accommodation, food and business administration (5 of total)	37.6	4.5	280
Valid N (listwise)			160

Table 1b: Sample Statistics for Western and Eastern European Countries (2004-2013)

Variables	West (17 Countries)			East (11 Countries)		
	Mean	St. Dev.	N	Mean	St. Dev.	N
TEU (in thousand)	5,412.4	5,249.5	148	444.0	399.9	63
Thousands of tonnes (road freight)	37,820.9	53,948.5	139	3,829.1	5,134.0	91
TKM, tonne-kilometer (road freight)	4,215.8	7,212.7	139	639.3	851.5	91
GDP per capita	47,726.0	21,178.4	170	13,264.5	5,120.6	110
FDIs (% of GDP)	7.6	17.8	170	5.8	8.0	110
Trade (% of GDP)	99.1	64.1	170	118.6	31.7	110
School enrollment, tertiary (% gross)	65.9	17.3	149	64.0	12.6	107
School enrollment, secondary (% gross)	107.5	11.2	162	97.9	6.1	107
% of individuals using the Internet	70.4	18.5	170	54.4	15.6	110
Employment manufacturing (% of total)	13.9	3.89	170	20.9	4.0	110
Employment trade, transport, accommodation, food and business administration (5 of total)	39.8	2.89	170	34.1	4.2	110
Valid N (listwise)			112			48

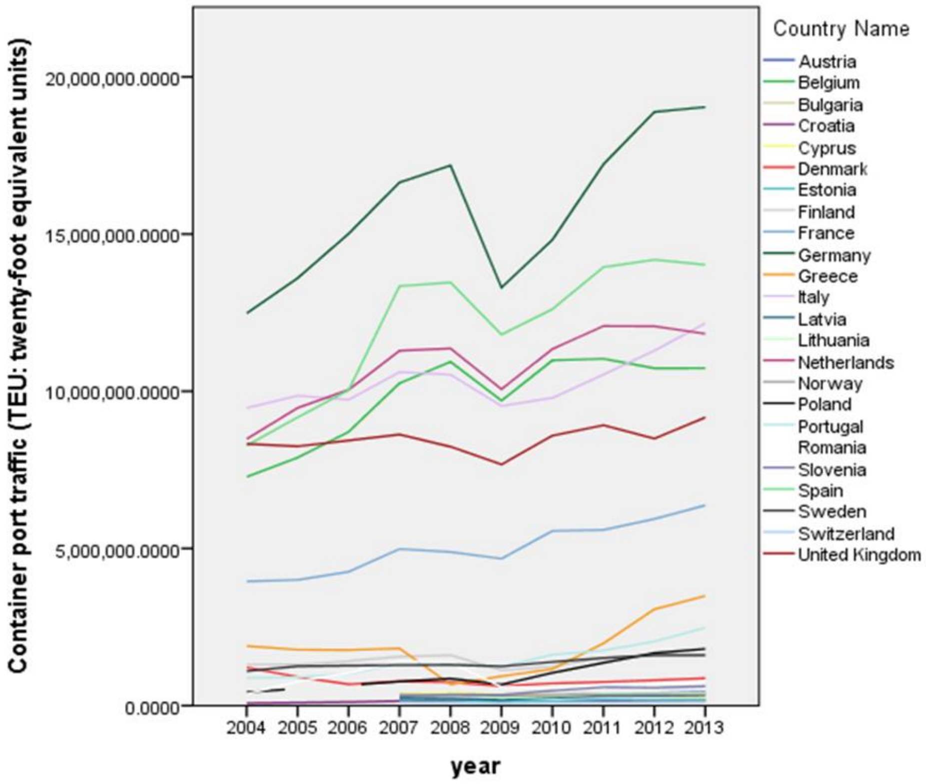

Figure 2. Container Port Traffic Volume Changes (TEUs)

4 Results

As shown in Table 2, our results illustrate that the constant is negative in all three regression models and significant at levels of 0.05 and 0.1 for Models 1 and 2. These findings suggest that the growth rate of transportation volume (TEU containers and road freight transport in thousands of tonnes and TKM) has slowed down, which implies by theory that the diffusion of transportation technologies is at the late stage of the diffusion process. However, an increase in transportation volume from the previous year (ΔLnTRAVOL) is positively associated with the growth rate of transportation volume. Among country-specific factors, openness of the economy as measured by trade (imports and exports of goods) is significantly associated with an increase in the growth rate of transportation volume (Models 1 and 2).

On the other hand, GDP per capita has no significant relationship with the growth rate of transportation volume in all three regression models. It is also notable that there is no regional difference in the growth rate in transportation volume between Western and Eastern European countries. These findings suggest that the level of economic development has no impact on an increase in transportation volume. Again, these results corroborate the fact that the diffusion of transportation technologies, such as the use of TEU containers and existing road freight transportation technologies is at the mature stage of the diffusion curve.

Our findings show that the diffusion of existing transportation technologies has passed over the saturation level, and its growth rate has decelerated, which might imply that emerging technologies such as the Physical Internet (for example, PI containers) can significantly increase transportation volume by triggering improvements in transportation efficiency and sustainability.

Table 2: Regression Results: $\Delta \ln H_t / H_t - \Delta \ln H_{t-1} / H_{t-1} = c + \beta \Delta \ln H_t + \gamma \Delta \ln Z_t$

Variables	TEU Model 1	Tonnes Model 2	TKM Model 3
Constant (c)	-.008* (.004)[1]	-.028^{+} (.016)	-.001 (.001)
ΔLnGDPCAP	.005 (.016)	.088 (.073)	-.002 (.000)
ΔLnFDI	-.001 (.001)	.000 (.003)	.000 (.000)
ΔLnTrade	.080** (.029)	.208* (.091)	.004 (.008)
ΔLnTER	.012 (.014)	.071 (.073)	.002 (.005)
ΔLnSEC	.001 (.011)	.020 (.045)	-.004 (.003)
ΔLnINT	-.018 (.012)	.048 (.041)	-.001 (.003)
ΔLnManuEMPL	.004 (.027)	.022 (.101)	.004 (.008)
ΔLnTREMPL	.048 (.055)	.117 (.179)	-.002 (.013)
ΔLnTRAVOL (β)	.014** (.005)	.034** (.011)	.003*** (.001)
WEST[2]	.003 (.002)	.009 (.007)	.000 (.001)
R^2	.500	.368	.327
F value	2.84***	1.95*	2.66***
Countries	24	27	27
Observations	126	141	141

$^{+}p<.1$, $*p<.05$, $**p<.01$, $***p<.001$
[1] robust (heteroscedasticity-consistent) standard error
[2] dummy variable—Western European countries coded as 1 and Eastern European countries coded as 0 (the classification is shown in Appendix—Table A1)
[3] dummy variables for year-specific effects.

5 Conclusions

The Physical Internet constitutes a powerful paradigm for a change toward a more sustainable and efficient way of doing logistics (Montreuil, 2011). To date, only a handful of simulations and case studies exist (Ballot et al., 2014), but further research is needed in order to identify relevant drivers and enablers. In this research project, we highlight the close relationship between country-specific factors and the growth of transport volume, as measured by the flow of containers in standard TEUs and road freight transported in thousands of tonnes and TKM, which are antecedents of the Physical Internet. In doing so, we extend the general framework of the Physical Internet by explicitly taking factors into account which in most cases cannot be directly influenced by logistics decision makers. This research therefore integrates a macroeconomic perspective into the overall Physical Internet framework.

The growth rate of transportation technologies examined in this research has slowed down after years of intensive use. Currently we might be at the dawn of the Physical Internet, a technological breakthrough in transportation. Several European companies are currently experimenting with the use of the Physical Internet, but these trials are in an early stage. From a theoretical point of view, a critical mass of users is essential for the adoption of new technologies such as PI containers. For the diffusion of new technologies, costs often outweigh benefits, which are usually small for early adopters. Furthermore, the benefits of new technologies might not be recognized by many industry participants. Thus, government subsidies and incentives can play a significant role for the diffusion of new technologies. The adoption of PI containers in advanced economies might influence their rapid diffusion in developing countries. The adoption by big industry players also might influence the adoption by other companies. While the present research on antecedents of the Physical Internet can inform about macroeconomic drivers of the diffusion of PI containers, it would be interesting for future research to consider the aforementioned factors, for example, government subsidies and incentives, as well as network externalities, which can further influence the adoption and use of the Physical Internet.

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Appendix

Table A1. Classification of Countries

Western European Countries (17)	Eastern European Countries (11)
Austria	Bulgaria
Belgium	Croatia
Cyprus	Czech Republic
Denmark	Estonia
Finland	Hungary
France	Latvia
Germany	Lithuania
Greece	Poland
Italy	Romania
Luxemburg	Slovakia
Netherlands	Slovenia
Norway	
Portugal	
Spain	
Sweden	
Switzerland	
United Kingdom	