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Drivers of railway container transports between China and Finland

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Abstract

On the China–Europe route, the sea used to dominate entirely continental transports, but in the last decade the railways started to gain some ground. However, it took number of years that railway volumes grew as significant, and finally coronavirus era (2020–2021) promoted much higher usage. This was the case not only on the main route Poland–China, but also on the more northern and lower-volume routes, such as Finland–China. This research uses regression analysis of the latter route to reveal factors that have an effect on rail container volumes. It is shown that Baltic Dry Index (BDI) and coronavirus related variables have influenced most container volumes on the Finland–China route. Oil price development has also played some sort of role. Interestingly, sea port handling of Finland does not play any significance in the model, nor does foreign trade between countries. Findings could be explained with the low starting ground of service, and dominance of sea transportation.

Keywords: Containers, Railways, Finland, China, Statistical analysis, Coronavirus

Introduction

The second coronavirus year of 2021 was again record-breaking for China–Europe railway container landbridge. Based on Chinese reports 15,000 container freight trains were handled in a year, and in container amounts this reached 1.46 mill. Twenty-foot Equivalent Units (TEUs) (van Leijen 2022; Unece 2022). As many of these containers serve China-Russia and other Central Asian and non-EU countries (which could be considered Europe or close to Europe from an Asian perspective), year 2021 volumes in the European Union-China route should be around one million TEUs (UTLC 2021). In the face of the severe impact of the pandemic, cargo transportation between China and Europe were in a "rapid growth trend" (reversal of the normal experienced trajectory). The number of China–Europe trains in 2021 compared with the 2016 level reached an annual growth rate of 55%. Both the container handling volume on the route and the trade value (USD 74.9 billion) realized significant growth against the trend (Liu 2022).

Since landbridge really started in 2015, this was already the sixth consecutive year of growth, and in the past three years, the growth has also been remarkable in terms of absolute volume. Landbridge connecting Europe and China has become an important alternative route and mode of transportation, especially at a time when airfreight is

facing continuous challenges. First, it was the lack of connections and passengers in the coronavirus years 2020–2021, but in the second half of 2021 and later, rapidly rising jet fuel prices and the Ukrainian conflict have continued to create challenges for air freight. If air freight is available, then its prices are significantly much higher than what is the situation in railway landbridge. It should be recalled that air freight between EU countries and China actually decreased in 2020, and already 2019 was a challenging year with a slight decrease compared to the previous year (Eurostat 2022a; Hilmola and Panova 2021). Based on Chinese statistics, landbridge freight trains increased by 29% in 2019 and by 50% in 2020 (Yeping 2022). However, the railway landbridge will also face great difficulties due to the Ukrainian conflict, and the year 2022 will be the year of much lower growth than before (Tabeta 2022; Ma 2022). This could be seen in one light as the beginning of a long-term decline, but it could also be identified as a year of change, when perhaps even the route that has grown too fast is facing a recession and needs changes in its structure. It may be that in a few years, China–Europe trains will use a more diverse set of routes, not only connecting Poland, Belarus and Russia, but expanding north and south as well. Officially Finnish (northern route) is one of the three main railway connections of China with Europe, and it has strategic role (Xin 2017). This is the research gap to be filled by this research—to analyze the development and growth drivers of the Northern Railway Container Landbridge.

This research analyzes the growth drivers of a less common China–Europe rail landbridge route, that of Finland. This alternative experienced growth after the launch of European routes in 2015, but growth slowed down in a few years, and in 2019 there was even very low volume. However, the coronavirus pandemic era changed everything, and growth was clearly present in 2020 (86.7% growth over 2019), and 2021 could have been considered a booming growth year (236.7% growth over 2020). However, these should be kept in context—despite the high growth in 2021, total container volumes were around 13,000–19,000 TEUs (estimated at 7–10 tons TEU freight weight). The research uses Finnish customs statistics on export and import by rail containers, and the analyses do not include transit traffic from other European countries (such as the Baltic States, Sweden, and/or Germany). Therefore, the container volume in 2021 is most likely 10–20% higher than the estimated container volume based on Finnish customs. This research is using monthly quantitative data and statistical models to explain volume in the route. To our knowledge it is seminal research of using such detailed analysis from China tied railway landbridge.

This research is intended to address following questions: What were the volume drivers of China-Finland container landbridge? Or was it just booming because alternative routes were developed further? What makes this examination interesting, is the feature of this route—export from Finland is typically much higher in net weight basis than import from China (in 2020 railway export from Finland was 19.2% higher than import from China to Finland; this based on Eurostat (2022bc). Situation is opposite in China-Poland route as in 2020 railway import from China to Poland was 78.8% higher than export from Poland (2022b, 2022c). This difference could be explained by the importance of Finnish forest industry products in Chinese markets. In general, China–Europe railway landbridge has faced empty container challenge due to trade imbalances (Tang et al. 2021), and these especially arising from Central European routes.

This research is structured as follows: Sect. "Literature review: competitiveness of China–Europe railway landbridge" reviews competitiveness of railway landbridge of China–Europe against of other transportation modes, and container market development in general. Used data of empirical part, and research environment is introduced in Sect. "Used data and research environment". Thereafter follows results of statistical analyses (regression models) in Sect. "Results". Results are discussed in Sect. "Discussion". Finally in Sect. "Conclusions" research is concluded, and further research avenues are being proposed.

Literature review: competitiveness of China–Europe railway landbridge

Since the beginning of the One Belt and One Road (OBOR) program, China has been consistently developing a rail-based landbridge with Europe. Around 2015–2016, container transportation started to become regular and was financially supported by the Chinese central government and the country's regions (Jiang et al. 2018; Kundu and Sheu 2019). Otherwise, it would have been difficult to open this continental railway service, because the sea transportation offered such low prices. Some research (such as Kundu and Sheu 2019) argued that the financial support was too aggregated and should have better targeted different cargo groups. Based on United Nations (2019), freight rate of Shanghai-Northern Europe for Twenty-foot Equivalent Unit (TEU) container in 2016 was 690 USD, which increased up to 876 USD in 2017. In comparison several research works have provided total costs for railway landbridge from China to Europe: Seo et al. (2017) estimated that Chongqing (China)-Duisburg (Germany) price for transporting Forty-foot Equivalent Unit (FEU) container would be 4436.6 USD (this included some road transportation for final-mile), where Zhang and Schramm (2020) gave price of 6350 USD per FEU for Shanghai (China) and Hamburg (Germany) route, and lastly Jiang et al. (2018) gave range of 2053.85 to 7349.88 USD per FEU. Of course, it should be emphasized that earlier given sea transportation rates do not reflect the true overall costs as very seldom transportation starts from and ends to larger sea port (connecting road, feeder and/or railway transportation is needed; Pomfret 2021), and to have corresponding FEU price from TEU, freight rate basically needs to be doubled (this is approximate as FEU will benefit from lower amount of liftings). However, difference was still significant in favour of sea transportation in 2016–2017—Zhang and Schramm (2020) estimated that sea-based transportation chain would cost as low as 2410 USD (62% lower from earlier railway mode-based price). Similarly, Seo et al. (2017) estimated that the lowest sea based transportation chain to cost around 2354.1 USD (46.9% lower than railway option in that research), and Jiang et al. (2018) gave area of 1500–2626 USD per FEU (from 27.0 to 79.6% lower as compared to railway alternative). Pomfret (2021) reported that in some specific situations sea freight might have only 10% lower freight rate as compared to rail (as both start point and destination are without sea port connection, like Chengdu, China and Warsaw, Poland). In this light, governmental support for railway landbridge within startup phase was justified. It should be noted that industrial clusters exist further west within railway landbridge, and they provide important scale economics for connectivity (Erokhin and Tianming 2022).

In real-life, competitiveness of market prices of railway containers in the route of China–Europe was much lower in pre-pandemic era as in some routes Chinese based

financial support was as high as 60–70% as was illustrated by Jiang et al. (2018). Pomfret (2021) estimated freight subsidies to have reached the level of 51–78%. However, container markets changed significantly, and in all markets, due to coronavirus pandemic, its following lockdowns and later-on applied economic stimulus programs. These sudden changes have been experienced before in globalized supply chains, and their effects can not be underemphasized as even small deviations in transportation or manufacturing based supply could cause implications for months to come (Habermann et al. 2015; Hu and Kostamis 2015). In the late 2020 and early 2021, railway-based China–Europe alternative became suddenly competitive. Freight rates started to approach 10,000 USD per FEU threshold (and in many cases continued further on from this level) in the sea route of China–Europe too (United Nations 2021), and therefore railways offered competitive alternative as it often served better final-mile transportation needs too (railway terminal much closer to customers than hub container sea port of Europe). It was rather striking change, that railway pricing was becoming competitive, even without any subsidies, like taking prices of Jiang et al. (2018) as an example. Extraordinarily high container freight rates persisted entire 2021 and have continued to remain relatively high in 2022 (although showing declining trajectory; SCFI 2022; Freightos Data 2022). Financial results of 2021 reveal the state of the container shipping industry: Evergreen (2022), CMA CGM (2022) and Hapag-Lloyd (2022) experienced all approx. 10 times higher profits in 2021 as compared to previous year 2020—largest container shipper in the world, Maersk, enjoyed growth of roughly six times in profits from previous year (Maersk 2022a). Interestingly, Evergreen's profit of 2021 was higher than revenue in 2020 (Evergreen 2022). This all indicates that container markets have changed structurally, and very low prices of previous decade are not standard in coronavirus era and beyond.

Railway landbridge also enjoys other competitive advantages as compared to sea transportation, apart of that of shorter distance and proximity for customers (as sea vessels are touring around number of container sea ports and hubs). Lead time is very important criteria, and having total transportation time around two or three weeks (typically below 20 days), it is very competitive as compared to sea transportation times of 30–45 days (Jiang et al. 2018; Seo et al. 2017; Zhang and Schramm 2020; Lasserre et al. 2020). For example, Maersk (2022b) offers route of AE10 Westbound, which starts from Xingang, China and ends to Gdansk, Poland. This route's entire transportation time is currently 46 days. Shorter lead time has in general great impact on overall costs as it will directly result in lower inventory holdings, lower tied working capital, and better business response on market changes. If products lose value over time (like electronics, spare parts, seasonal products, fashion etc.), then value of shorter lead time is even economically higher. Railway landbridge also holds considerable environmental emission advantage—it is significantly much better than air freight, and compares itself with low emitting container transports at sea. So, it is having both low emissions and needed delivery speed. Although, costs have been an issue before coronavirus pandemic, they are less so currently. Not only have container rates at sea increased, but also, they have increased considerably in air freight. Even before Ukrainian conflict, IATA estimated air cargo to cost more than four USD per kg to transport (IATA 2022)—in case of 10–15 tons net weight sea container, this corresponds freight price of 40,000–60,000 USD per FEU. This price level is not extreme in Europe-China setting as Zhang and Schramm

(2020) estimated air freight cost to be 32,490 USD per FEU (this in year 2017). Number of years earlier Verny and Grigentin (2009) used rate of 71,120 USD per TEU for air route of Shanghai-Frankfurt. As Ukrainian conflict resulted on closure of airspace of Russia e.g., for European and North American air freight companies, it will inevitably lead to higher freight rates by air (due to lower overall capacity available and longer routes used). Recent research has found that agility is critical capability for financial success of manufacturing and retail, and not that of emphasizing low cost and waste reduction (Gligor et al. 2015). Changes in 2020–2022 in China–Europe based supply chains do favour more agile companies than classical cost optimizers. These nonfinancial competitiveness factors increase the sustainability of railway landbridge. In the aftermath of Ukrainian conflict, it has been popular for companies to develop and initially use so called Middle Corridor (Trans-Caspian), even if it has much higher costs (Unece 2022). However, the situation in the Southern Corridor (through Kazakhstan, Uzbekistan and Turkmenistan) does not yet seem to be promising for similar positive developments, despite large infrastructure investments, plans and joint-actions completed (Horák 2023; Pomfret 2021).

Used data and research environment

Empirical data of this research is arising from the number of different national sources of Finland. For railway container transports of Finnish route was used Finnish Customs (2022) Uljas service. In this database and its query portal, it is possible to search import and export flows to particular country by different transportation modes. In this research, we are interested from continental railway landbridge with China. Therefore, trade of Finland with China was chosen as search factor together with railway transportation mode. However, this is not entirely accurate estimate of railway container transportation volumes in this route. It is impossible to know level of transit service of containers e.g., to Sweden or Germany (as they are recorded to customs data of these countries—at EU level such is available, but it is delayed and limited). It is known that such have existed, but they have not been that significant (like in Polish route). In addition, this model is intended to estimate drivers of Finland-China country pair, so including other transit countries in here would lower the accuracy of results. In this research examination period is set as 2016–2021, and having monthly observation frequency. In 2016 Chinese container trains started to have some regular service features from Finland, and volumes were not sporadic as in the start-up phase of 2015 (in some months test trains caused spikes, but then in the following months volumes declined to zero). In January of 2016 volumes were in dataset zero as well, but thereafter each month dataset is having some volume, and in the entire observation period strongly growing volume. Growth analysis in annual terms illustrates the situation: In 2020 railway container volumes between China and Finland were 101.2% higher than in 2016, however, in 2021 these volumes were 577.2% higher as compared to 2016. It could be said that year 2021 was strong in Chinese landbridge even as comparing it to Finnish-Russian railway container volumes (where container transports have longer history between countries and often, only way to connect). Landbridge volumes grew as larger than Finnish-Russian in some months of late 2021 (like in Sept. and Nov.). Figure 1 illustrates growth of this railway container transports further. In Chinese press this new route between China and

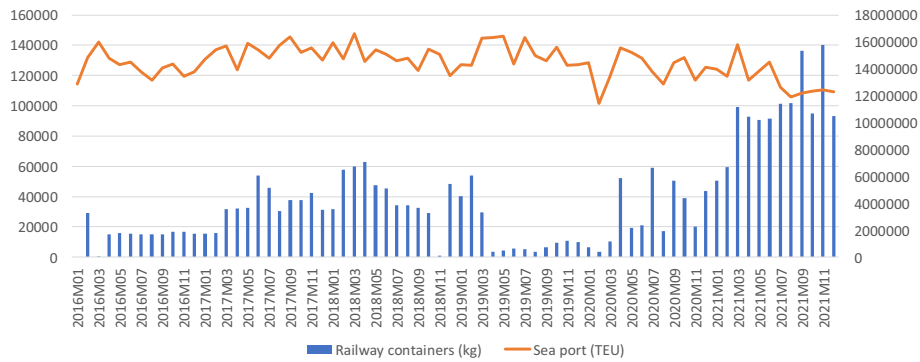

Fig. 1 Container handling amounts (monthly) in all Finnish sea ports (y-axis on left, in TEUs) and railway container transportation between China and Finland (y-axis on right, in freight net weight, kg)

Table 1 Descriptive statistics of independent variables (2016–2021, apart of Covid, which is from Feb 2020 to Dec 2021)

	Average	Median	SD	Min	Max
BDI	1425.7	1251.0	901.7	317.0	5167.0
Sea port (TEU)	128,578.4	129,255.0	10,522.3	101,698.0	147,717.0
Helsinki (TEU)	40,759.5	40,897.0	3747.2	33,461.0	49,921.0
HaminaKotka (TEU)	53,576.6	53,710.5	5286.8	39,723.0	64,123.0
Covid (cases)	12,464.9	8639.0	20,459.8	10.0	100,027.0
Covid (tests)	381,557.1	417,844.0	223,618.6	398.0	825,000.0
Covid (deaths)	76.5	45.0	81.0	0.0	301.0
Chinese trade (total)	694,011,399.9	692,557,226.5	111,310,422.5	499,134,333.0	1,170,104,762.0
Chinese exports	274,522,211.2	282,383,361.0	40,730,407.9	164,836,114.0	354,415,571.0
Chinese imports	419,764,204.1	396,040,233.5	90,446,027.4	265,967,948.0	850,066,690.0
Brent (oil) price	57.6	59.2	14.1	18.4	83.5

Finland was said to have increased significantly since 2020, and it was having great development potential (Zhu and Chen 2021). In research we used a number of independent variables in regression models, and their descriptive statistics are provided in Table 1.

As statistical analysis in the following is based on regression analysis, number of different variables were used as potential explaining independent variables. First set of variables, in total three of them, consisted sea port handling of containers in Finland. The first one was handling in overall in all sea ports, and then in two largest ones separately (HaminaKotka and Helsinki). The idea of including sea port handling is the possible competition between these transportation modes in continental transports, and that railway volumes would in parts act as a substitute for sea transports. There is also another view including container handling, and that is the state containerized trade market overall. It could be argued that, if sea ports have increasing volumes, then railway connection could also have opportunity to prosper. This reasoning does not see transportation modes as substitutes for each other. Whatever is the logic, it could be justified that sea port handling is included as one explaining variable.

Sea port handling data is originating from Statistics Finland (2022). Sea port handling overall in Finland and railway container volumes between China and Finland are shown together in Fig. 1. One way of examining relationship a priori regression models is to

complete correlation analysis—in coronavirus era (from Feb 2020 to Dec 2021) it seems in Fig. 1 that sea port handling is declining, while railway volume is increasing. However, their correlation in this era is -0.268 (indicating that lowering sea port volume and increasing railway in landbridge), however, this correlation co-efficient is not even close to any statistical significance.

Third alternative transportation mode that of air was left from regression analysis due to the reason that air freight volumes are so low (in coronavirus era railway containers transported 4.3 times more than air freight), and they did not significantly change in coronavirus era as compared to earlier (in the period Jan 2016 to Jan 2020 (on the average): 1,650,863.6 kg per month vs. 1,678,312.6 kg per month in the coronavirus era). Of course, there was significant decline in the spring of 2020 (due to global lockdown), but thereafter major airline called Finnair decided to keep Chinese routes open (from Finland), and even used passenger planes for this activity, and this increased air freight volumes back to normal. Air freight is having positive correlation with railway container volumes, but this is not statistically significant (entire examination period of 2016 to 2021 or only coronavirus era).

Typically, alternative transportation modes in long-distance service are dependent on the economic soundness of these as compared to the most dominating one, that of sea transportation. Latter is often the most cost efficient and sets cost level for the other alternatives. Therefore, Baltic Dry Index (BDI) was used as a proxy for freight rate levels at sea (Investing.com 2022). It is of course not directly container transportation-based index, but it is most well-known and widely used all over, and reveals the state of shipping markets well. As shipping, and transportation in general, is coupled to the price of oil (e.g., concerning shipping, Choi and Yoon 2020), in the following regression models' monthly price of Brent oil is used as one potential explaining variable (U.S. Energy Information Administration 2022).

As examination period consists of two years of coronavirus era, and this was said to have partially caused boom in railway container transports between China and Europe, it was important to be incorporated in the models. Finnish Institute for Health and Welfare (THL) weekly Covid-19 statistics were included in the model just transforming them as monthly. These statistics included coronavirus related amounts of tests, cases, and deaths in a particular month (Finnish Institute for Health and Welfare 2022). In one smaller regression model in the following, coronavirus era was also treated as a binary value—being zero before Feb 2020 and thereafter having value of one.

As transportation is always a service and dependent on changes of trade, Finnish trade with China was used also as variable. These included total trade, but also separately export and import. Data is originating from Finnish Customs and its Uljas monthly reporting service (Finnish Customs 2022).

In regression models it is important to recognize the quality of parameters by analyzing potential multicollinearity of used independent variables. Challenge in using numerous variables is that these have too high correlation with each other (either negative or positive). This brings instability in the model results and gained regression coefficients could vary a lot, if new data is brought in or model is altered. Earlier research indicates that correlation coefficient of 0.8 would be level (positive or negative), where multicollinearity becomes challenge (Shrestha 2020). As Table 2 illustrates, used variables of this

Table 2 Correlation coefficients of used independent variables of this study

	BDI	Sea port (TEU)	Helsinki (TEU)	HaminaKotka (TEU)	Covid (cases)	Covid (tests)	Covid (deaths)	Chinese trade (total)	Chinese exports	Chinese imports	Brent (oil) price
BDI											
Sea port (TEU)	−0.407***										
Helsinki (TEU)	−0.187	0.759***									
HaminaKotka (TEU)	−0.332**	0.885***	0.54***								
Covid (cases)	0.4***	−0.406***	−0.237*	−0.279*							
Covid (tests)	0.681***	−0.51***	−0.242*	−0.319**	0.695***						
Covid (deaths)	0.341**	−0.358**	−0.124	−0.251*	0.792***	0.68***					
Chinese trade (total)	0.744***	−0.229	0.078	−0.18	0.703***	0.696***	0.608***				
Chinese exports	0.471***	0.227	0.326**	0.164	0.216	0.268*	0.196	0.657***			
Chinese imports	0.711***	−0.388***	−0.054	−0.299*	0.772***	0.741***	0.665***	0.94***	0.36**		
Brent (oil)price	0.555***	−0.056	0.031	−0.093	0.249*	0.197	0.048	0.505***	0.624***	0.346**	
Coronavirus	0.509***	−0.522***	−0.177	−0.338**	0.457***	0.821***	0.623***	0.521***	0.043	0.626***	−0.084

*Statistical significance below 0.05 level; **Statistical significance below 0.01 level; ***Statistical significance below 0.001 level

study do have numerous correlations (typically they are positive, but sea port handling is having e.g., negative correlations with number of variables), and having high statistical significance. However, only few of them are above 0.8 correlation level. Between sea port handling of containers (overall) and that of HaminaKotka sea port there is such (+0.885), and between coronavirus era and testing activity (+0.821) as well as Chinese imports and total Chinese trade (+0.94). In the following analysis all of these are resolved, so that multicollinearity is not any issue in final smaller regression models. These are not used in any final model at the same time. It should be noted that coronavirus era binary variable is used only in smaller model together with BDI (too strong connection to testing activity is not any issue then).

Results

Regression models

Statistical analysis was started with the largest possible regression model, which was used to detect most important variables as well as functionality of the entire model. Results of it are shown in Table 3. Just by examining p value of different independent variables, it could be said that Baltic Dry Index (BDI) is having high significance (p value being < 0.01), but also the amount of Covid (tests) of Finland is such (p value < 0.01). As

Table 3 Regression model (monthly) of container transportation volumes in China and Finland route, where foreign trade is used as variable in overall but also in export and import (observation period: Jan 2016 to Dec 2021)

Regression statistics					
Multiple R					0.867
R square					0.751
Adjusted R square					0.706
Standard error					1,972,533
Observations					72
ANOVA					
	df	***SS***	***MS***	***F***	***Significance F***
Regression	11	7.05953E + 14	6.42E + 13	16.49	2.63801E-14
Residual	60	2.33453E + 14	3.89E + 12		
Total	71	9.39406E + 14			
		Coefficients	**SE**	**t stat**	***P*-value**
Intercept		− 1,291,942.87	4,298,124.13	− 0.301	0.765
BDI		2104.03	624.95	3.367	0.001
Sea port (TEU)		139.46	101.76	1.370	0.176
Helsinki (TEU)		− 100.42	148.32	− 0.677	0.501
HaminaKotka (TEU)		− 116.53	130.69	− 0.892	0.376
Covid (cases)		22.89	51.05	0.448	0.656
Covid (tests)		7.60	2.50	3.047	0.003
Covid (deaths)		15,629.20	8836.36	1.769	0.082
Chinese trade (total)		− 0.61	0.32	− 1.898	0.063
Chinese exports		0.60	0.32	1.844	0.070
Chinese imports		0.60	0.32	1.866	0.067
Brent (oil) price		41,827.69	29,594.98	1.413	0.163

examining coefficients of these variables, it became apparent that higher freight price levels of BDI will result in higher volumes in railway container connection. Similarly, higher test amounts of Covid will lead to higher transportation volumes of railway containers. However, three trade variables (all in monetary amounts, EUR) did not have consistent direction on railway containers, and they did not have statistical significance. The model in Table 3 shows that both export and import separately would possibly lead to higher volumes in railway containers, but trade overall will not, and actually its effect is negative. This could be due to multicollinearity possibility identified earlier between total trade and import. This controversy was such difficult one, that additional regression model was run, where Chinese trade (overall) was excluded as an independent variable. Interestingly, as overall trade was excluded, still both export and import remained not significant in statistical terms (Table 4). However, import from China is rather close to significance, and it is having negative effect on railway container volumes. This only illustrates controversy of trade variables in the model.

What is rather striking finding in Table 3, is the unimportance of container handling within Finnish sea ports in total, and then in two largest sea ports individually (Hamina-Kotka and Helsinki). Similarly, second larger regression model in Table 4 supported this finding as overall trade with China was excluded as one potential variable. Actually, in both of Tables 3 and 4 statistical significances on any of sea port related container handling volume variables was not even close to significance. Similarly, Covid (cases) was

Table 4 Regression model (monthly) of container transportation volumes in China and Finland route, where foreign trade is separately export and import

Regression statistics					
Multiple R					0.858
R Square					0.737
Adjusted R Square					0.693
Standard Error					2,014,159
Observations					72
ANOVA					
	df	***SS***	***MS***	***F***	**Significance F**
Regression	10	6.91939E + 14	6.92E + 13	17.06	3.24999E-14
Residual	61	2.47467E + 14	4.06E + 12		
Total	71	9.39406E + 14			
		Coefficients	**SE**	**t stat**	***P*-value**
Intercept		− 1,686,605.85	4,383,686.555	− 0.38	0.702
BDI		2258.88	632.675	3.57	0.001
Sea port (TEU)		153.42	103.635	1.48	0.144
Helsinki (TEU)		− 168.10	147.008	− 1.14	0.257
HaminaKotka (TEU)		− 118.54	133.441	− 0.89	0.378
Covid (cases)		− 15.54	47.850	− 0.32	0.746
Covid (tests)		7.32	2.544	2.88	0.005
Covid (deaths)		24,328.72	7713.789	3.15	0.003
Export to China		− 0.02	0.009	− 1.82	0.073
Import from China		− 0.01	0.007	− 1.43	0.157
Brent (oil) price		64,323.01	27,689.828	2.32	0.024

not statistically significant in either of these larger models. However, Covid (deaths) and Covid (tests) of Finland were significant in the latter model, where overall Chinese trade was excluded (Table 3). Situation is similar with Brent (oil) price—in the first regression model (Table 3) it is not at all statistically significant, but in latter model of Table 4 it is showing that higher prices lead to higher railway volumes in statistically significant terms.

Even if these both models in Tables 3 and 4 are having rather high R^2 values (explanation power), ranging from 73.7% to 75.1%, both models are having rather high standard error, around two million kg (of net railway container freight). Comparison of standard error could be made to average monthly railway container freight, which was in 2016–2021 period 4.28 mill. kg, and it had highest volume of 15.8 mill. kg during Nov 2021.

Out of Table 4 model, and its statistically significant values was smaller model developed, which is presented in Table 5. In this model, BDI and corona virus related variables are statistically significant. Highest statistical significance is in BDI freight index (p value of < 0.001), followed by two coronavirus variables having p value of below 0.05. BDI freight index, and Covid tests as well as deaths of Finland are all having positive coefficients. Oil price in turn is not any longer statistically significant, however, its co-efficient still stays as positive. This smaller regression model was having rather high R^2 value that of 68.6%. However, its weakness is still rather high standard error.

To further illustrate coronavirus effects, was very small, only two variable model, being developed (Table 6). In here model included BDI freight index, and then binary variable of coronavirus era (being zero from Jan 2016 until Jan 2020, and changing as one from Feb 2020 until the end of 2021). BDI was again in this model having highest statistical significance (p value of < 0.001), but binary coronavirus era variable was also rather high in significance (p value < 0.01). Based on this model, coronavirus increased monthly

Table 5 Smaller regression model (monthly) of container transportation volumes in China and Finland route (further development of Table 3 results)

Regression statistics					
Multiple R					0.828
R Square					0.686
Adjusted R square					0.668
Standard error					2,097,262
Observations					72
ANOVA					
	Df	***SS***	***MS***	***F***	**Significance *F***
Regression	4	6.44706E + 14	1.61176E + 14	36.64	3.26361E-16
Residual	67	2.947E + 14	4.39851E + 12		
Total	71	9.39406E + 14			
		Coefficients	**SE**	***t stat***	***P*-value**
Intercept		− 1,026,520.20	1,078,191.35	-0.95	0.344
BDI		1658.55	474.74	3.49	0.001
Covid (tests)		4.66	2.11	2.20	0.031
Covid (deaths)		13,270.81	6047.62	2.19	0.032
Brent (oil) price		35,603.52	22,259.34	1.60	0.114

Table 6 Small regression model (monthly) of container transportation volumes in China and Finland route

Regression statistics					
Multiple R					0.780
R Square					0.609
Adjusted R Square					0.598
Standard Error					2,307,393
Observations					72
ANOVA					
	df	***SS***	***MS***	***F***	**Significance *F***
Regression	2	5.72046E + 14	2.86E + 14	53.723	8.55544E-15
Residual	69	3.6736E + 14	5.32E + 12		
Total	71	9.39406E + 14			
		Coefficients	**SE**	**t stat**	***P*-value**
Intercept		84,037	512,827	0.164	0.870
BDI		2506	352.80	7.103	8.66E-10
Coronavirus		1,954,088	677,494	2.884	0.005

railway container volumes by 1.95 mill. kg (corresponding approx. additional 195 TEU containers per month, if net weight of these is 10 tons per TEU).

Sea freight prices as leading driver

Earlier in all regression models it became evident that BDI freight index is leading driver for container transports by rail. It is worthwhile to examine its relationship with railway container volumes in the entire observation period of 2016–2021 (Fig. 2)

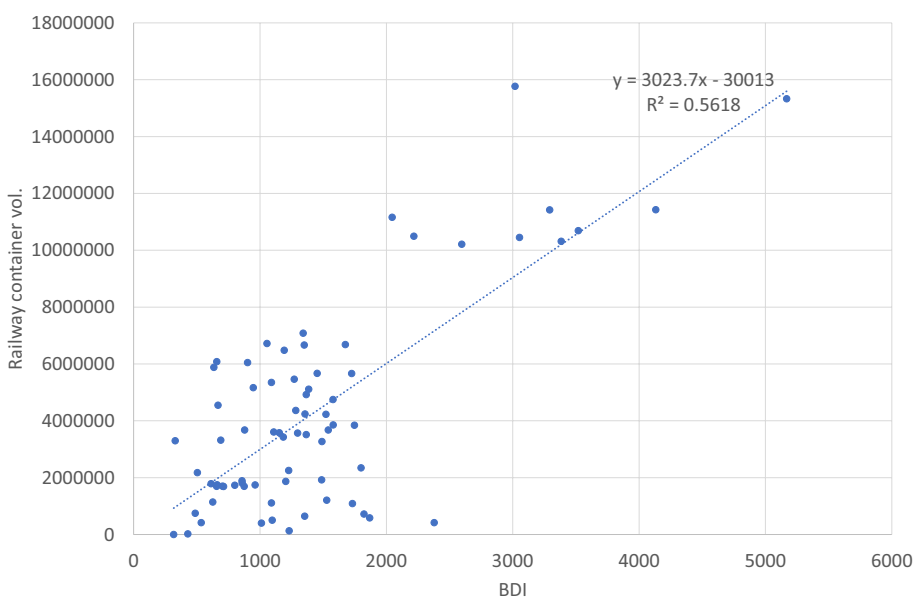

Fig. 2 Scattergram from Baltic Dry Index (BDI) and railway container volume (kg) between China and Finland (observation period: Jan 2016 to Dec 2021)

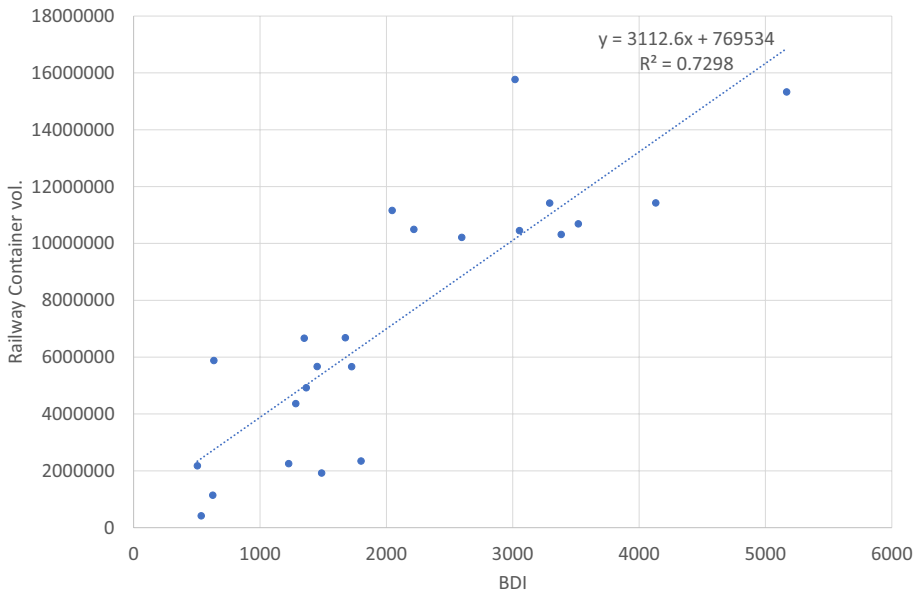

Fig. 3 Scattergram from Baltic Dry Index (BDI) and railway container volume (kg) between China and Finland during coronavirus era (observation period: Feb 2020 to Dec 2021)

and during coronavirus era that of Feb 2020 to Dec 2021 (Fig. 3). What is striking in these Figs. 2 & 3, it is the coefficient of regression line on the changes of BDI. In both cases it is somewhat above 3000. Coronavirus era did not increase this coefficient that much higher, however, railway container transportation volumes are in corona era more aligned around regression line, and R^2 value is much higher than in the entire dataset regression (72.98% vs. 56.18%). BDI freight index value of 1500 to 2000 seems to be some sort of threshold for higher railway container transportation volumes. Below this area, and particularly below 1000, data in Fig. 2 seems to be lacking direction as railway container volumes could be low or high whatever freight rate is, and forecast is therefore uncertain. This could be due to two reasons: lower freight rates create uncertainty to the use of higher cost railway transports and many of these low freight rate observation points are from early era of Chinese connection (in other words, representing kick-off or start-up phase). It was also tested with chi square statistical test, what is the implication of dividing entire data of 2016–2021 with two variables that of railway container volume (dividing point 4.5 mill. kg for low and high) and BDI freight rate (dividing point 1500 for low and high). Still within this grouping, chi squared test shows in Table 7 that higher BDI freight rate drives railway container volumes (p value < 0.001).

BDI index is also most robust in its coefficient changes as taking these from Tables 3, 4, 5, 6. On the average, BDI index is having coefficient of 2131.87 and standard deviation is 16.7%. Covid measures of tests and deaths (often statistically significant in different models) show standard deviations of 24.9% and 32.8% (in Tables 3, 4, 5, 6). This illustrates that covid based independent variables are rather uncertain and do not necessarily provide needed robustness. However, BDI index is robust measure and most important driver of railway landbridge volumes.

Table 7 Chi square statistical test as entire data from 2016–2021 is grouped based on railway container volume (threshold of 4.5 mill. kg) and BDI index (threshold of 1500)

Should be		Freight rates		Actual		Freight rates	Actual
		1500.00				1500.00	
		Low	High			Low	High
Railway vol. 4,500,000.00	Low	33.35	15.65	Railway vol. 4,500,000.00	Low	35	10
	High	15.65	7.35		High	14	13
	Total	49	23		Total	49	23

Discussion

Statistical and regression models are always based on past data, and assumption that causalities and drivers also hold in the future. If the early 2022 would be analyzed based on regression model independent variables, volumes should have stayed at high level of 2021 and even show some growth. This could be justified with several developments. Baltic Dry Index was recording low performance in January 2022, however, it has thereafter recovered to the price level of mid-2021 (Investing.com 2022). So, the main driver is still showing support for railway container volumes. Due to Omicron variant of coronavirus, testing and casualties remined at high level (Finnish Institute for Health and Welfare 2022). Of course, it should be reminded that mortality rate (deaths per detected virus cases) was getting very low, and official testing was already limited in Finland in 2022 that it is not required nor provided in mild cases and testing numbers as well as coronavirus cases are much higher than what official statistics in 2022 show. Anyway, coronavirus was still present, its effects are still going-on, and it could be seen that e.g., in China larger cities experienced wide-scale lockdowns in 2022 (including Shanghai, being largest container sea port in the world; Will 2022). Therefore, it could be assumed that coronavirus effects were still present in railway landbridge container volumes. So, this should support high volume level of railway containers. It is of course expected that after 2022 virus effects will start to dampen and disappear as variants of virus become milder and milder (and virus itself is weaking considerably). In the second regression model Brent (oil) price was statistically significant variable, and it was having positive relationship with railway container volume. In 2022 oil prices only climbed higher.

Despite that regression model variables show support for high volumes at railway landbridge, it is known that this was not the reality in 2022. Somehow already in January 2022 railway container volumes were roughly half from December of 2021 in Finnish route. Companies were already adapting to the tense situation in the border areas of Ukraine. Thereafter, in 24.Feb 2022 Russia started full-scale military invasion to Ukraine, and it has had its effects in logistics sector too. For example, both railway freight and passenger traffic were fully stopped in the late March 2022 between Finland and Russia (VR Transpoint 2022a). Freight operations freeze was based on the information that governmentally owned Finnish railway company interpret western sanctions (from UK) in a way that they can not any longer operate Russian trains. However, this decision did not hold for many days, and freight flows were opened again (passenger transports remained as closed). Railway freight challenges anyway continued after this—it has been demanded by politicians to be closed entirely, and governmental company has responded

that it will scale-down operations as promptly as it can, but taking into account agreements with their customers (VR Transpoint 2022b). In Finland there are some private railway companies, which could operate international freight traffic (and which are not necessarily under any sanctions, political influence or need necessarily to follow either these). However, these companies lack resources for international transport operations and border-crossing procedures. In addition, they would need agreements with Russian side to start full-scale operations. All this resulted in situation where railway container landbridge faced significant issues and challenges in 2022 (annual volumes declined by 82.2% from 2021), which have also persisted in 2023 (although it does not directly concern Russia and serves trade of Europe/Finland and China). It is unknown, how long this situation could continue. If comparison point is taken from history, changes in Russia and its relationship with Europe could even lead in a little bit longer term to some similarity, which was experienced after Lenin's Bolshevik revolution in 1917. For example, Finnish trade due to Bolshevik revolution declined drastically—Russian share of total trade was in 1916 around 73%, but it declined to 0.04% in 1920 (Finland also became independent out of Russian empire in Dec 1917, which naturally fostered foreign trade decline with Russia). Some recovery was detected in trade during 1923–24, when Russian share increased to the level of 3.3–4.6% from overall Finnish trade. So, if using this as an analogy, it could be forecasted that current railway difficulties will persist for five to six years. It is of course open question, how long negative situation remains in the railway route of Finland-China. It could be assumed that such freight traffic is at first stages opened as relations will slowly start to improve between west and Russia. It could still be an option that railway container traffic with China is not going to be stopped for longer period of time at all (as it does not concern Russian trade or economy directly). It should be reminded that even in the midst of cold war (in 1970s and 1980s) Russian based railway landbridge was used in the container transportation flows of Asia, Middle East and Europe (Mote 1984). Containers were then mostly originating or ending to Japan—currently routes have changed (earlier route was entirely Russian or Soviet dominated, but now Kazakhstan plays important role), and operations are dominated by China. It is also known that main Chinese landbridge to Europe via Poland is still functional, and operating, but of course it is having its challenges, and growth will not be as strong as it was in the earlier years (Tabeta 2022; Ma 2022).

Conclusions

Railway landbridge connecting Europe with China has been major success story of previous decade. Volumes have already grown in 2021 to the level up to 1.46 million TEU containers (van Leijen 2022; Unece 2022), and in 2022 this volume was sustained with some small growth (Mingyang et al. 2023). This growth story was initially financially supported by the Chinese state and its regions, but in the coronavirus years this support was no longer needed as container transport prices increased so much (and they have remained at relatively high levels). Northern railway route of this landbridge that of China-Finland has also experienced growth, however, its development was not as straight as large Polish based. At the beginning of 2016–2018 growth was clearly present in the Finnish route, but in 2019 volumes decreased significantly and almost completely disappeared. Coronavirus era of 2020–2021 was the reason for rebirth in terms of volume, and very important

single event. This research highlighted that in regression models, both the level of ocean freight rates (BDI) and coronavirus-based measures were the contributors to container volumes. In coronavirus measures, both levels of testing in Finland and deaths due to the virus were found to be statistically significant. In addition, a smaller model of only coronavirus era with binary variable showed statistical significance.

What is interesting about the Finnish route is the contradictory role of foreign trade between China and Finland. Therefore, an additional regression model was developed (and total trade was excluded), but this did not change the results regarding the trade variables. However, oil prices were a statistically significant and positive variable in this situation. Interestingly, in this additional model, Finland's sea port throughput had no relationship with China-Finland rail container volume. As concluded, the sea port handling of containers has been on a declining path in the last two observation years of this study (despite the coronavirus era). Thus, the railway route has had a unique need, which it has fulfilled, and its volumes cannot yet be stated to be away from sea ports (at least not in the models of this research). For example, in 2020 volumes of railway containers were rather small at Finnish landbridge, but sea port handling in Finnish sea ports decreased by almost 8% from 2019. In 2021, the big growth year for Finnish railway landbridge, sea port handling declined by another almost 6%. Perhaps, railway landbridge has attracted some growth from air freight customers, as it struggled during the pandemic period (and just maintained the same previous volume level). Also, the role of sea transport is so dominant that the marginal volumes at the railways do not yet show any relation between these two modes, and some volumes most probably still come from this mode (in the success of the railway landbridge).

As practical implication of this study, it is well shown that companies need to assure versatility in their long-distance transportation chains, especially when freight rates at sea rise and remain high. Pandemic era and military conflict in Ukraine have revealed that relying on single mode is not optimal nor feasible solution. Sea transportation has its problems with overheating rates, capacity and long lead times. Air freight is fast and connects major cities well, but only in times of normal global business environment. Rail landbridge also has its challenges now (Ukrainian conflict and subsequent sanctions and reactions), but still offers relatively short lead time at reasonable cost. Therefore, it is important for supply chains to manage difficult times by using all possible modes of transportation and maintaining supply chain flexibility—this to ensure ability to operate in any possible environment. The future remains rather unknown and unpredictable.

As further research, it would be important to follow development of railway landbridge in years 2022–2024. Currently conflict in Ukraine is creating obstacles for it, and connectivity e.g., to Finland is also facing serious difficulties. In spring of 2022 entire railway operations were even shutdown to Russia, and this was re-executed in the autumn of 2022. It is yet impossible to foresee, what are the long-term effects of armed conflict on railway freight. It is of course having negative effects, however, is it minor or major and how long time effects will take place, that remains to be seen. Anyway, freight levels of sea transportation remained relatively high in 2022, and coronavirus was still challenging issue in both Europe and China. These should support further growth. For these reasons, this research should be repeated in the coming years.

Abbreviations

TEU	Twenty-foot equivalent unit
OBOR	One belt and one road
FEU	Forty-foot Equivalent Unit
BDI	Baltic Dry Index

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